Radiation in Imaging

Understanding and Managing the Risks

Ryan Harvey, M.D.
Chair, Radiology, Sarasota Memorial Hospital
President, Radiology Associates of Florida, Radiology Partners

Radiation in Imaging

Understanding and Managing the Risks

Fluoroscopy Focus

“I have seen my death.”

Anna Bertha Ludwig
Wife of Wilhelm Roentgen,
1895

Marie Curie

1867 – 1934

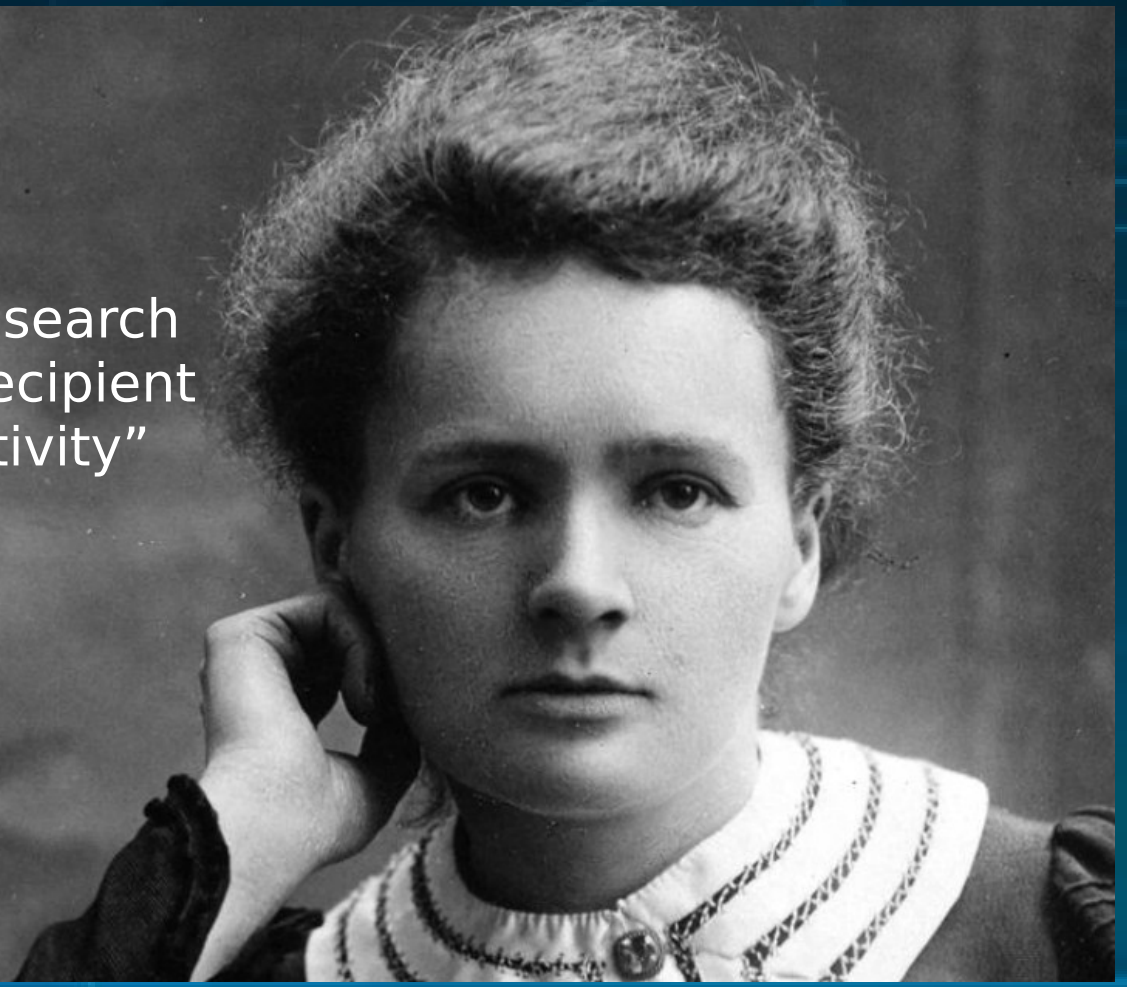
Pioneer of radioactivity research
First female Nobel Prize recipient
Coined the term “radioactivity”

Marie Curie

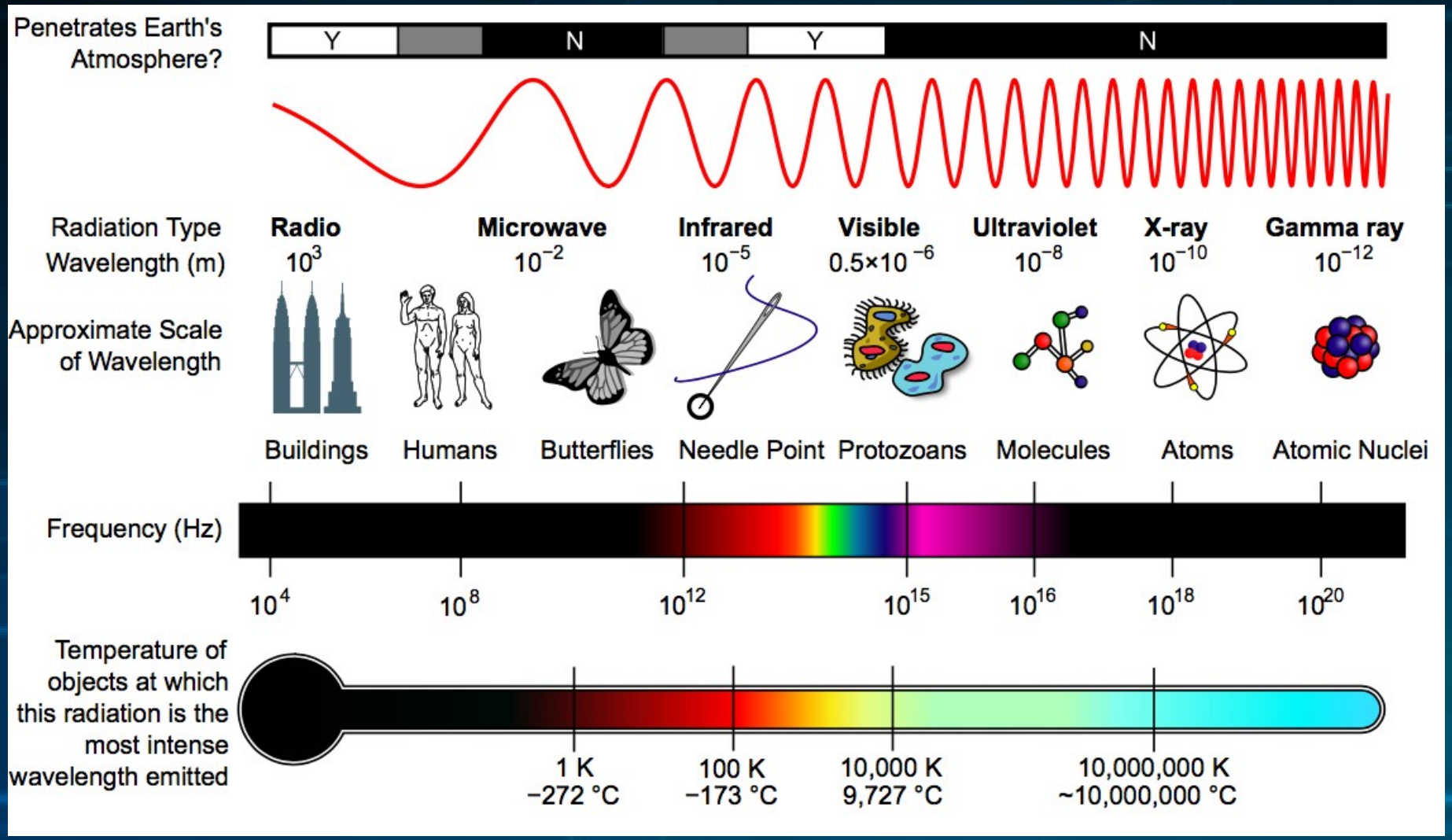
1867 – 1934

Pioneer of radioactivity research
First female Nobel Prize recipient
Coined the term “radioactivity”

Died of aplastic
anemia from radiation
exposure

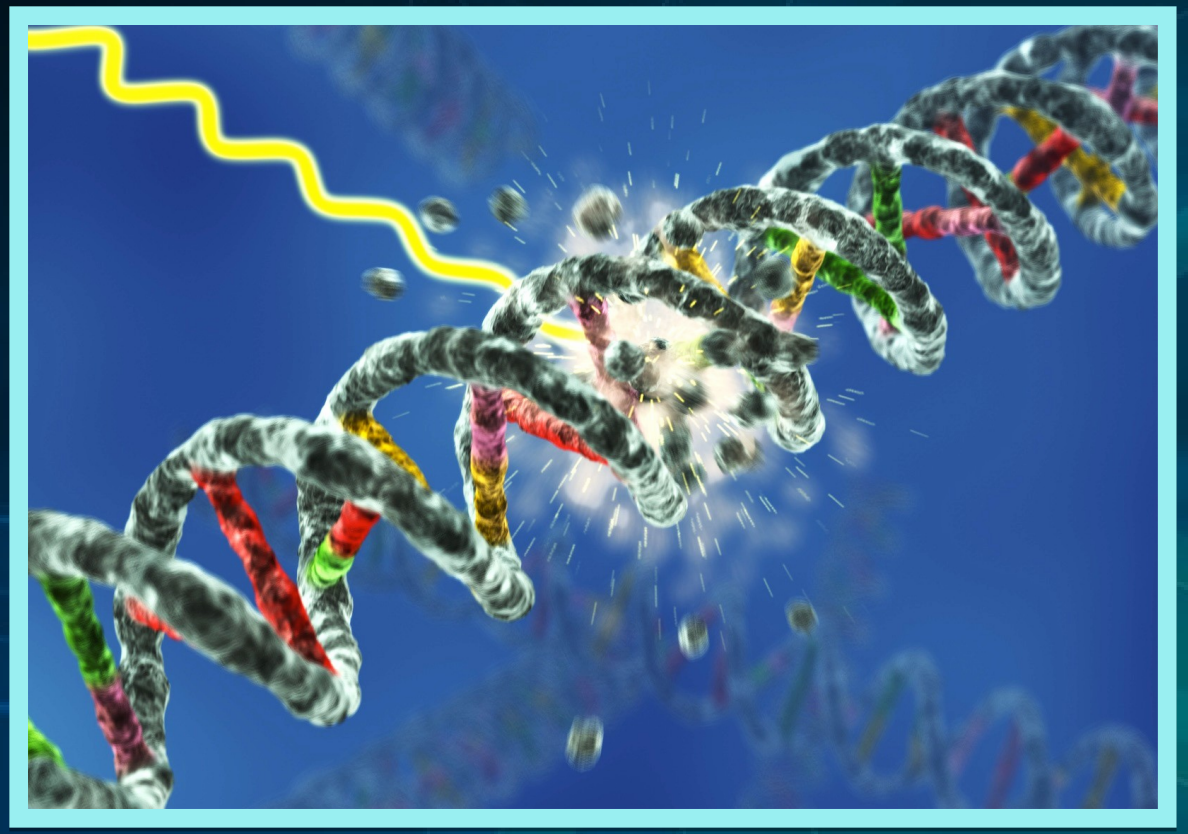


Mechanism of Radiation Damage



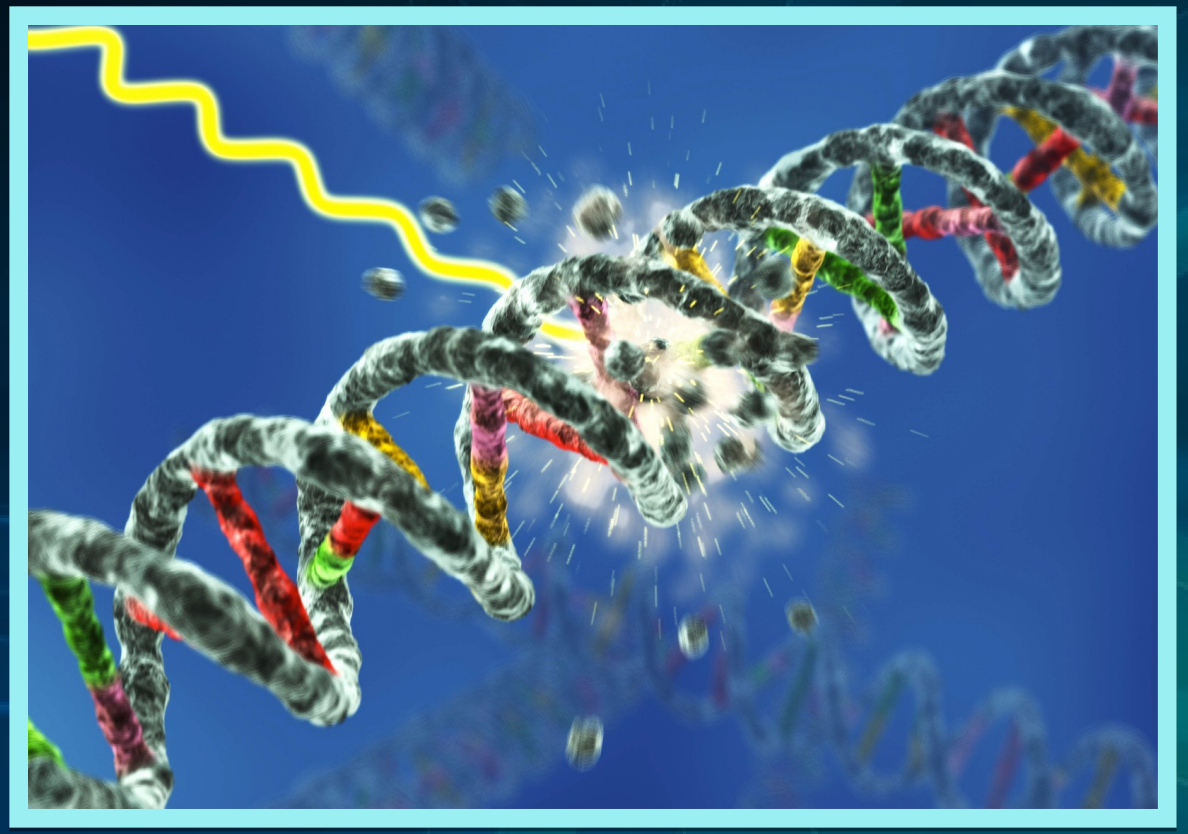
Inductiveload, NASA - https://commons.wikimedia.org/w/index.php?curid=2974242

Mechanism of Radiation Damage



- Single strand breaks
- Double strand breaks
- Base pair alteration

Mechanism of Radiation Damage

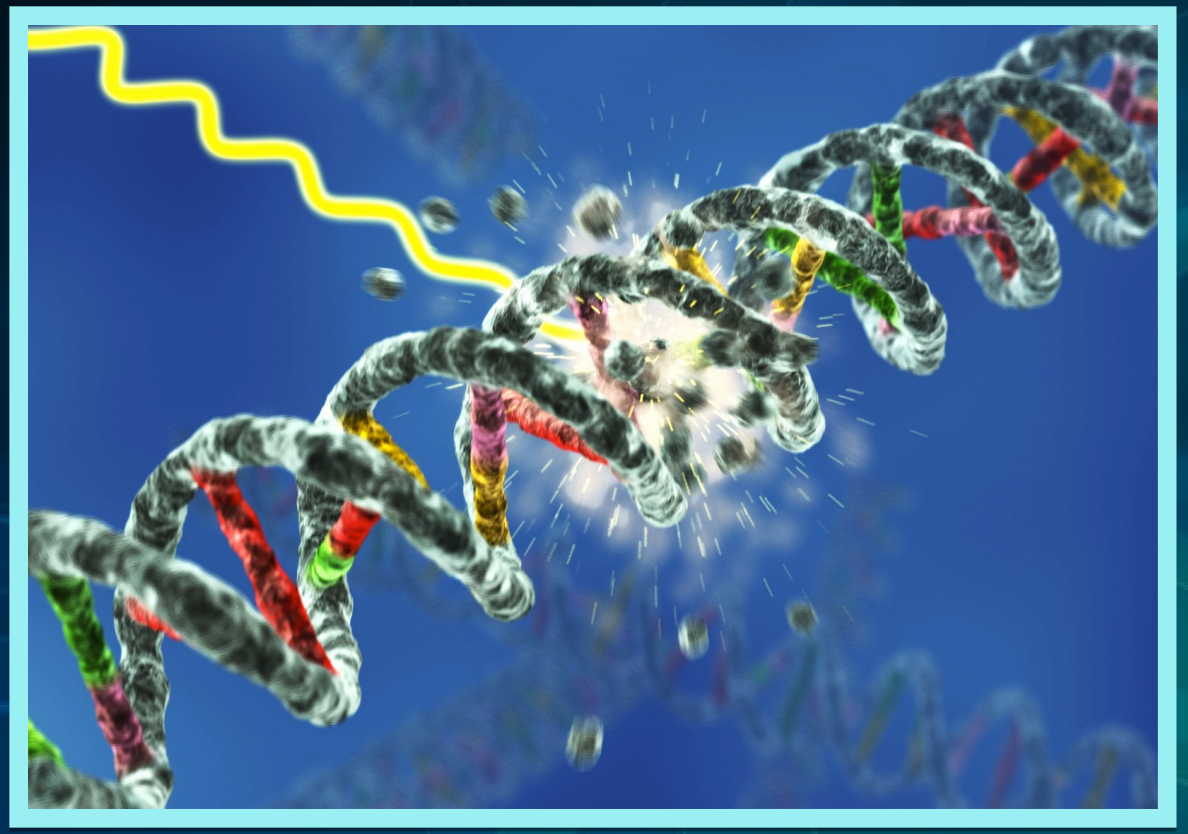


- Single strand breaks
- Double strand breaks
- Base pair alteration

↓ ← Repair mechanism

Mutation

Mechanism of Radiation Damage



- Single strand breaks
- Double strand breaks
- Base pair alteration

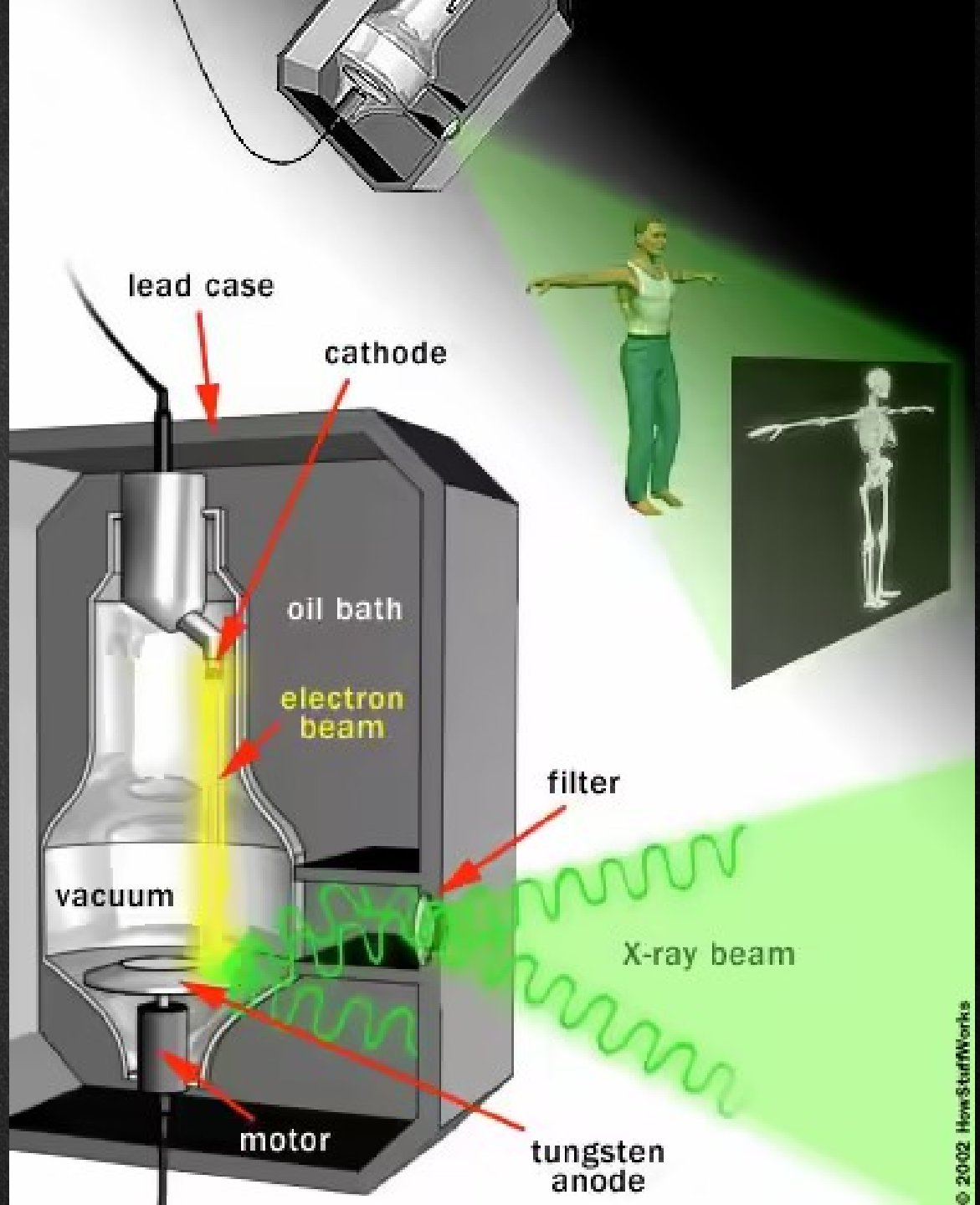
↓ ← Repair mechanism

Mutation

↓

- Activated oncogene
- Deactivated tumor suppressor gene

How are X-rays produced?



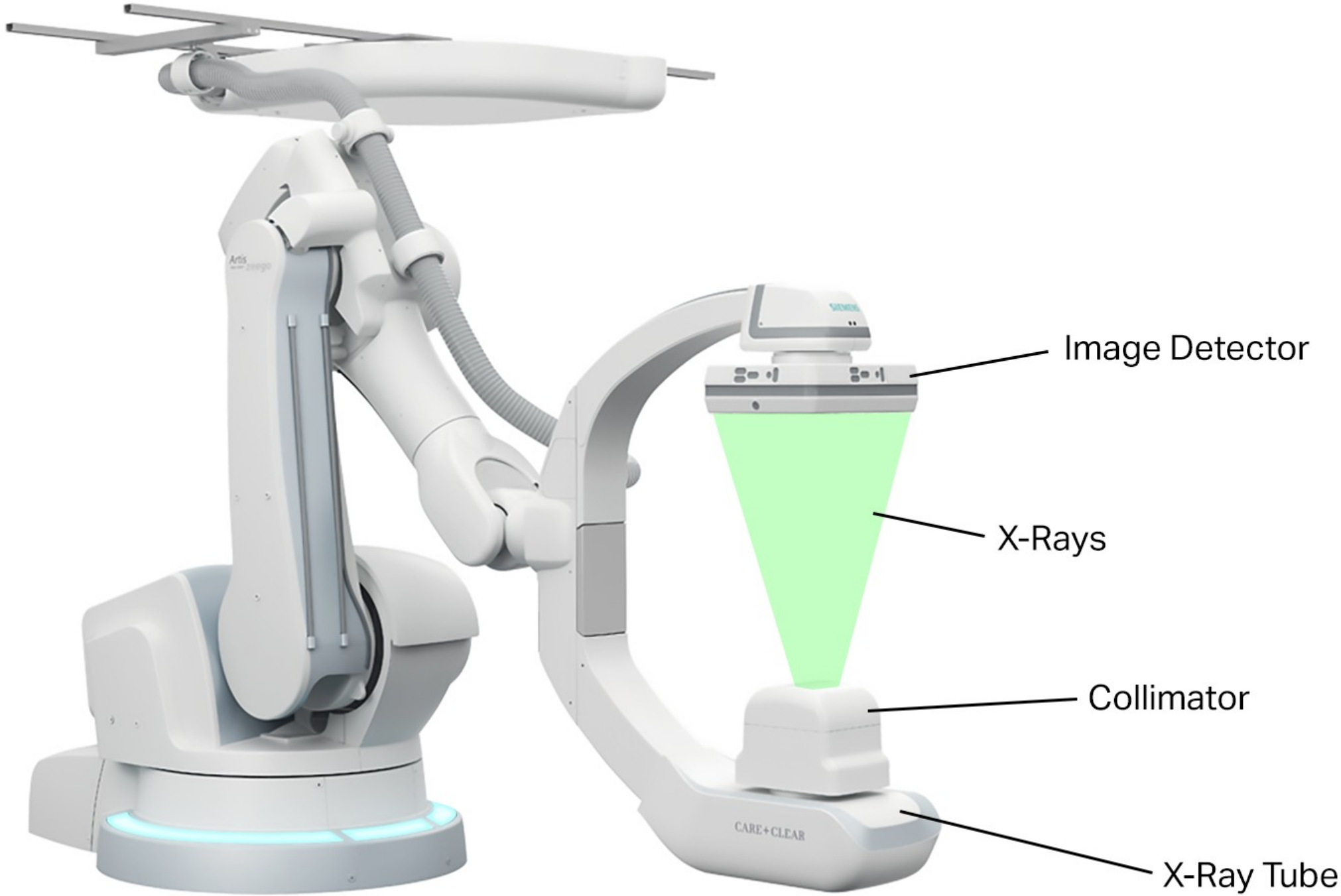


Image Detector
X-Rays
Collimator
X-Ray Tube
CARE+CLEAR

Tap, don’t park.

Strategy: Use Fluoroscopy Gently

Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

- ✓ Watch the fluoroscopy timer (everyone in the room)

Strategy: Use Fluoroscopy Gently

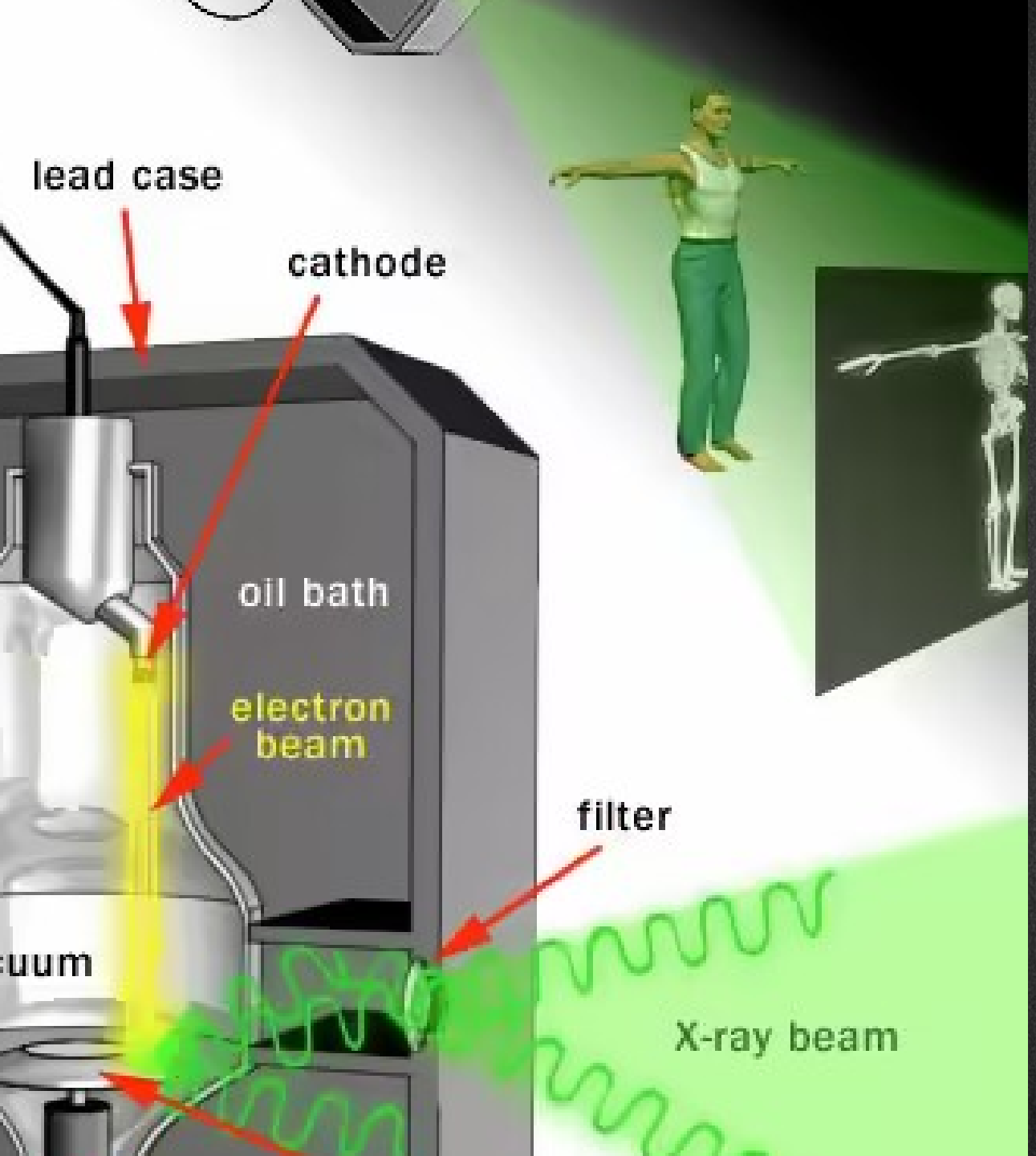
Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

- ✓ Watch the fluoroscopy timer (everyone in the room)
- ✓ Set pulse rate as low as possible (0.5 fps – 30 fps)

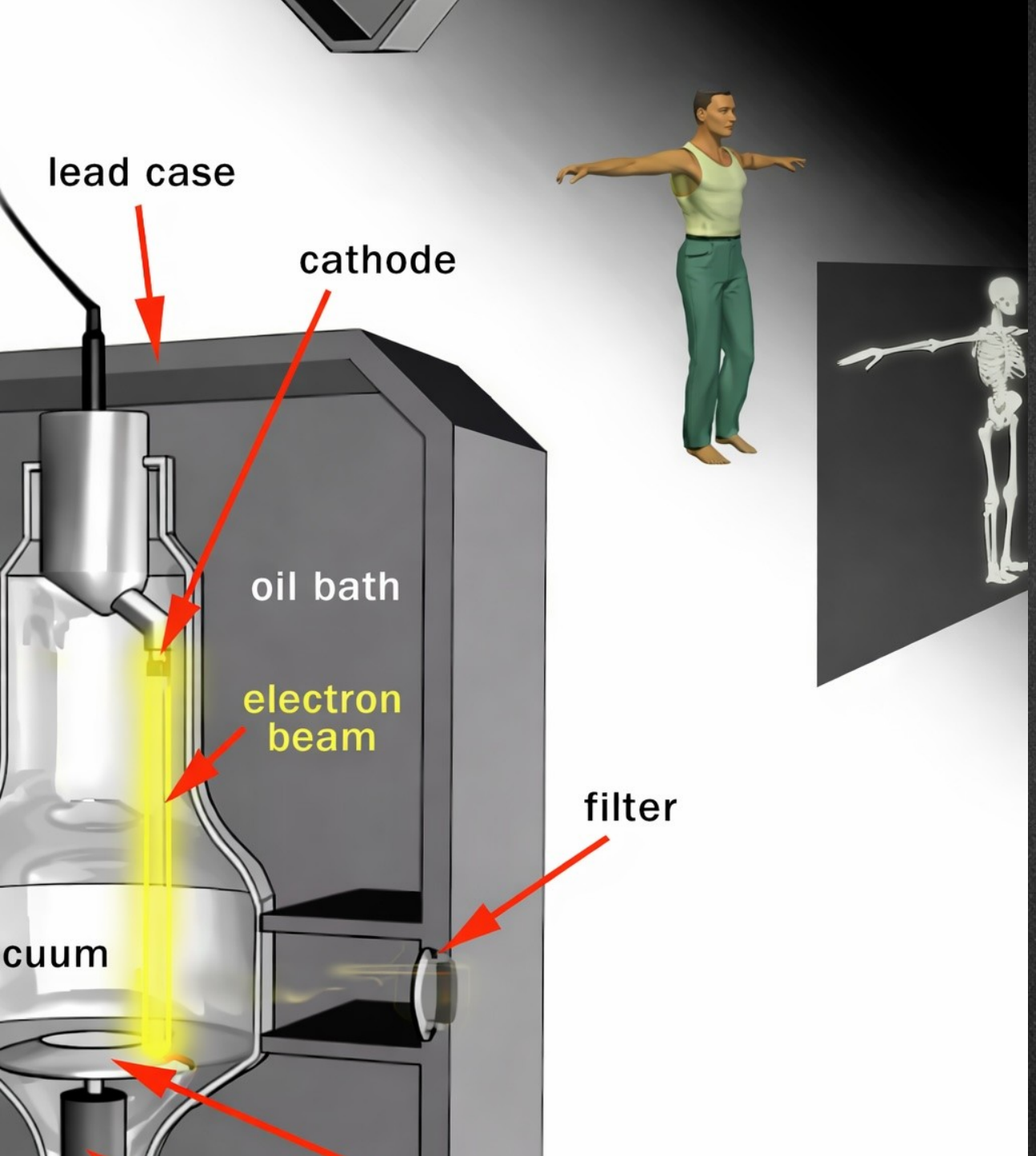
Strategy: Use Fluoroscopy Gently

Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

- ✓ Watch the fluoroscopy timer (everyone in the room)
- ✓ Set pulse rate as low as possible (0.5 fps – 30 fps)
- ✓ Use fluoroscopic spot images (one-tenth the dose) rather than radiographs when possible



Last Image Hold



Last Image Hold

The image persists on-screen after lifting off the pedal

Strategy: Use Fluoroscopy Gently

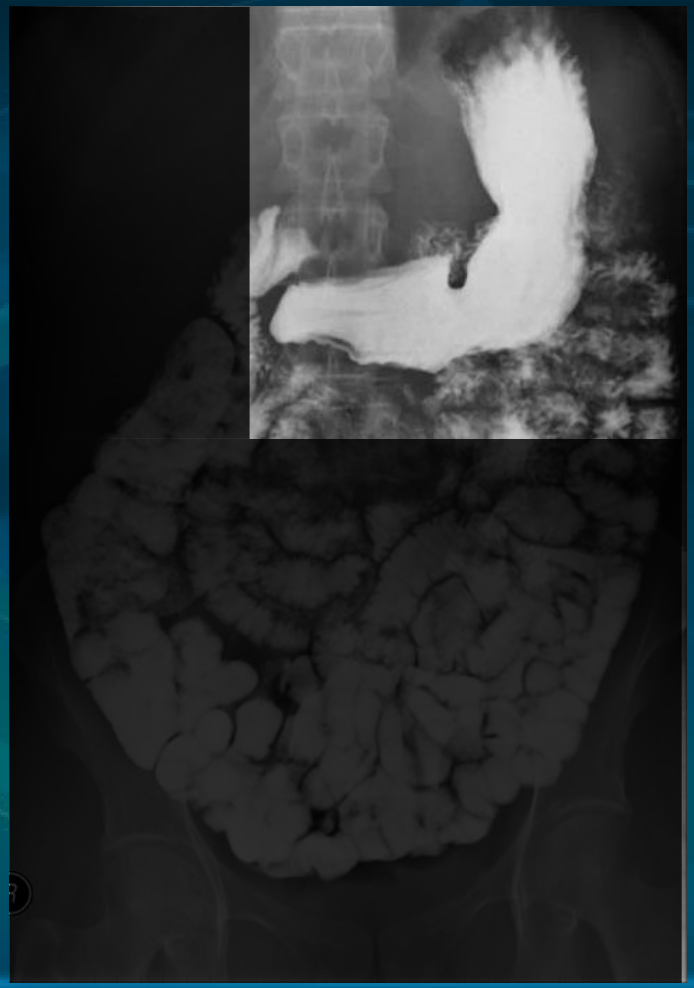
Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

- ✓ Collimate tightly

Strategy: Use Fluoroscopy Gently

Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

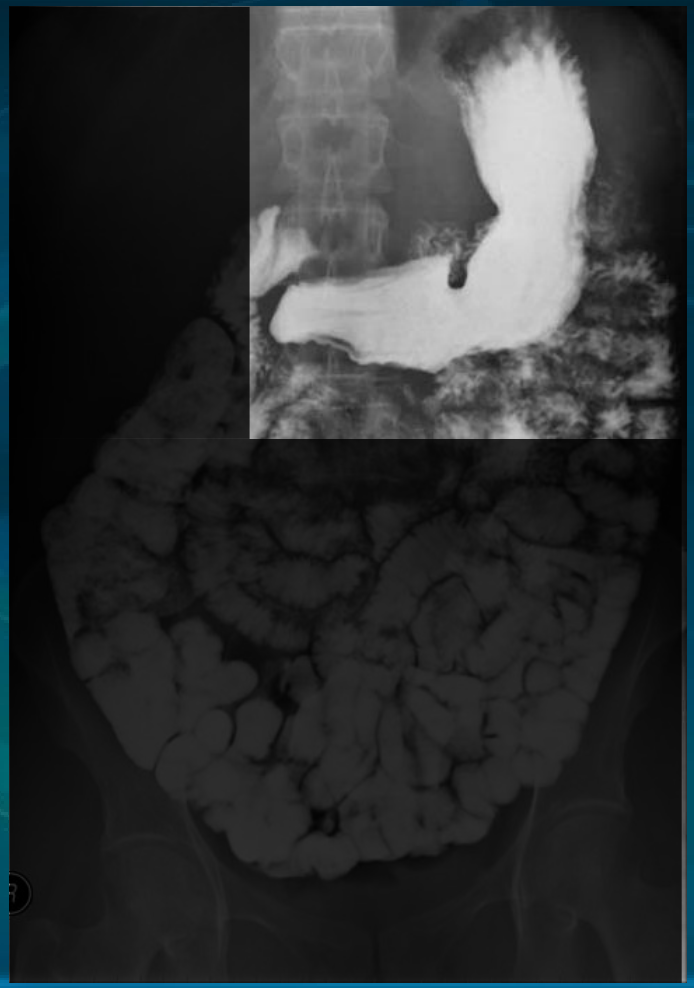
- ✓ Collimate tightly



Strategy: Use Fluoroscopy Gently

Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

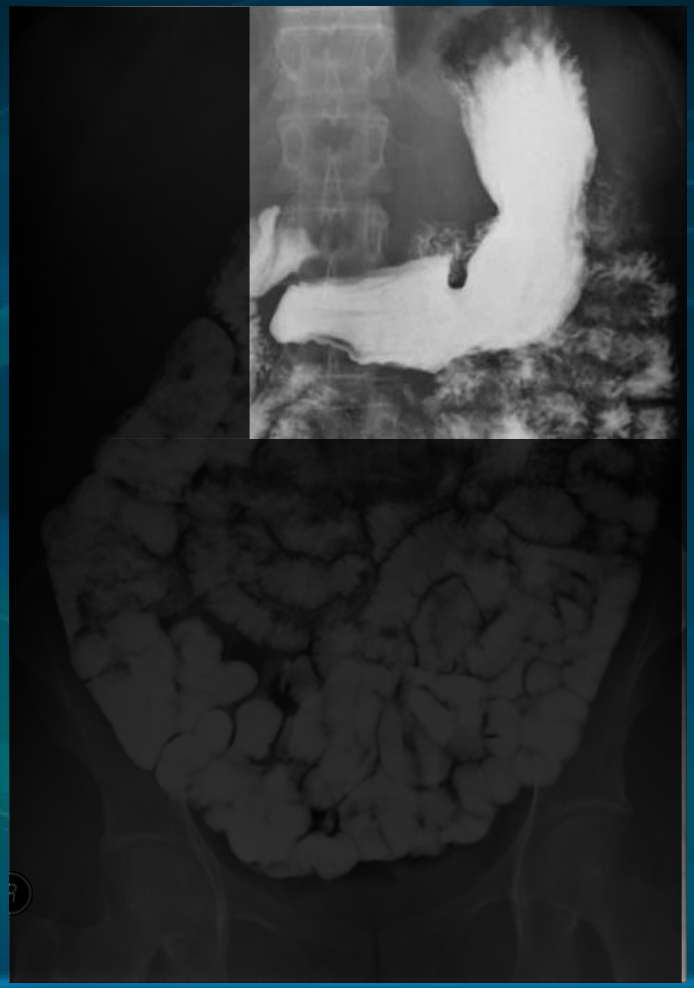
- ✓ Collimate tightly
- ✓ Magnification increases radiation dose[23]



Strategy: Use Fluoroscopy Gently

Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

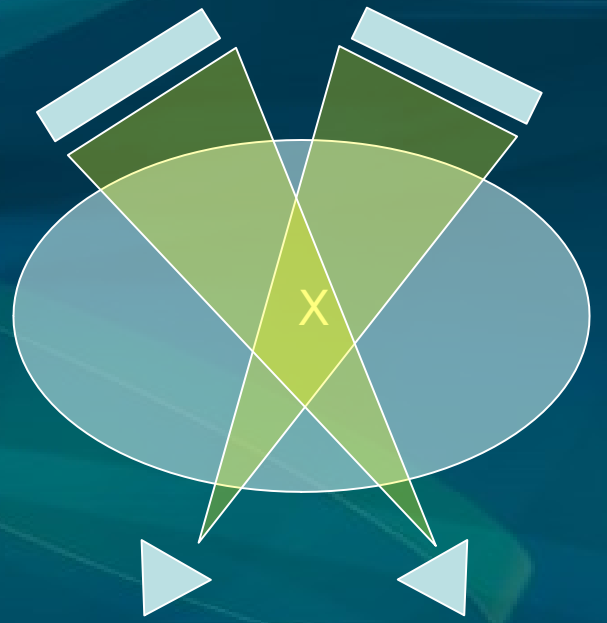
- ✓ Collimate tightly
- ✓ Magnification increases radiation dose[23]
- ✓ Keep the detector (image intensifier) as close to the patient as possible

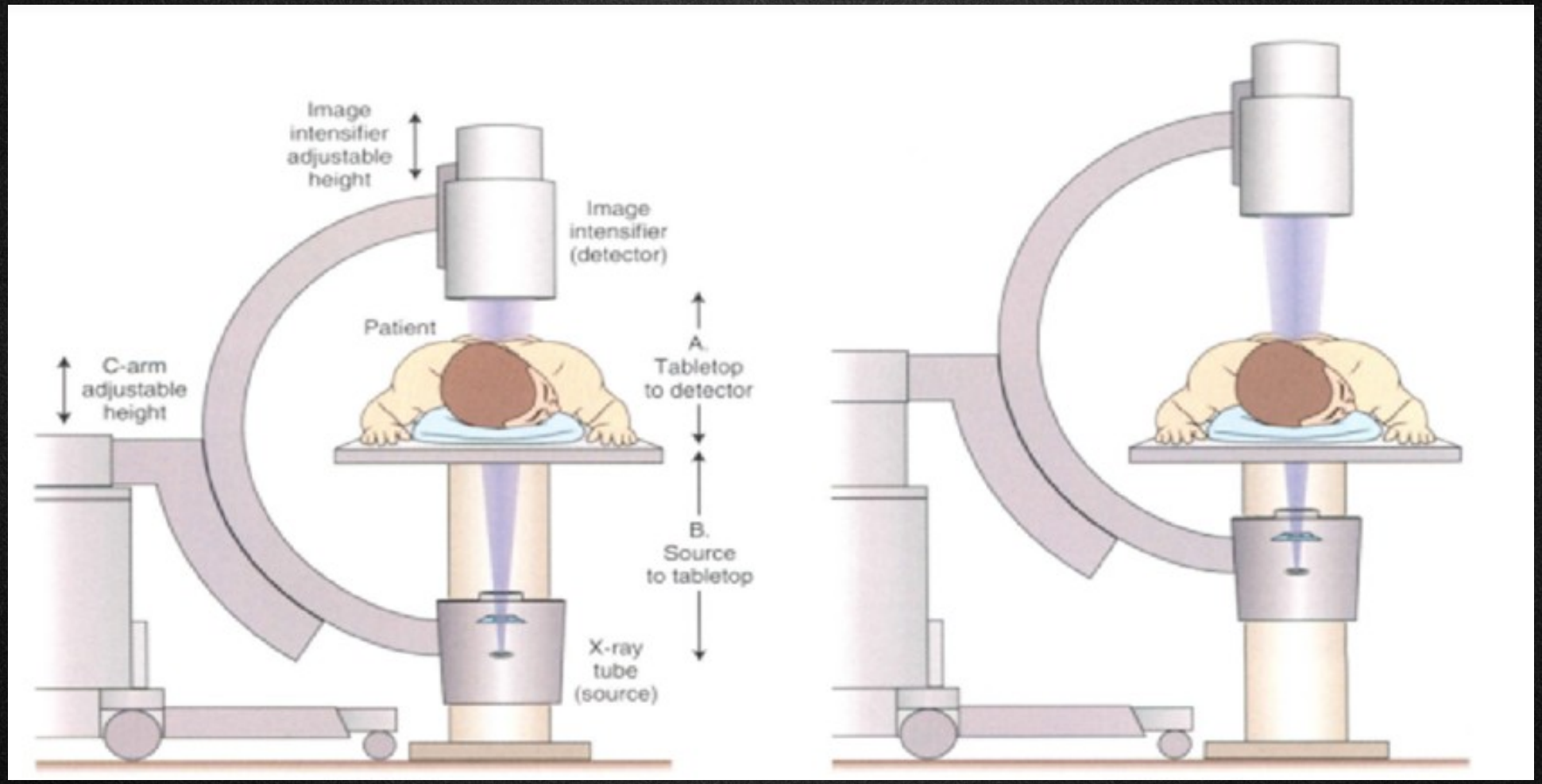


Strategy: Use Fluoroscopy Gently

Fluoroscopy radiation dose varies significantly from operator to operator and with experience[21,22,23]

- ✓ Collimate tightly
- ✓ Magnification increases radiation dose[23]
- ✓ Keep the detector (image intensifier) as close to the patient as possible
- ✓ Spread the skin dose



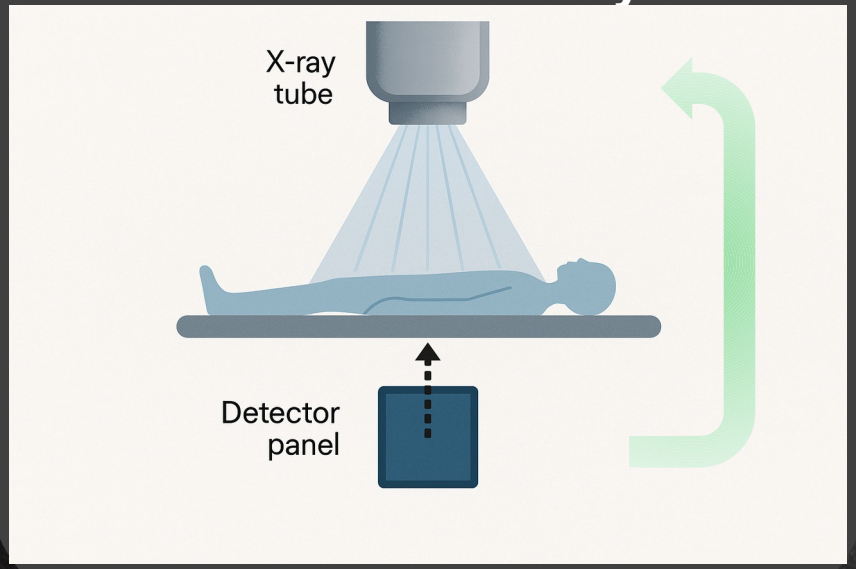


Better

Worse

What is Automatic Exposure Control (AEC)?

AEC adjusts the delivered dose to keep signal at the detector steady



These scenarios cause AEC to increase the dose

- Torso in the FOV
- Torso oblique instead of prone/supine
- Thicker anatomy in the beam path
- Lead shielding in the beam path

*Tip: optimize geometry + collimation *before* you step on the pedal.*

Strategy: Optimize Hardware and Examination Protocol

Hardware parameters

ALARA voltage and current settings
Pediatric-appropriate settings
CT automated tube current modulation
Iterative reconstruction

Hardware QA

Oversight by radiation safety officer (RS
Establish Pass / Fail criteria for dose
ACR Certification
Regular QA by medical physicist

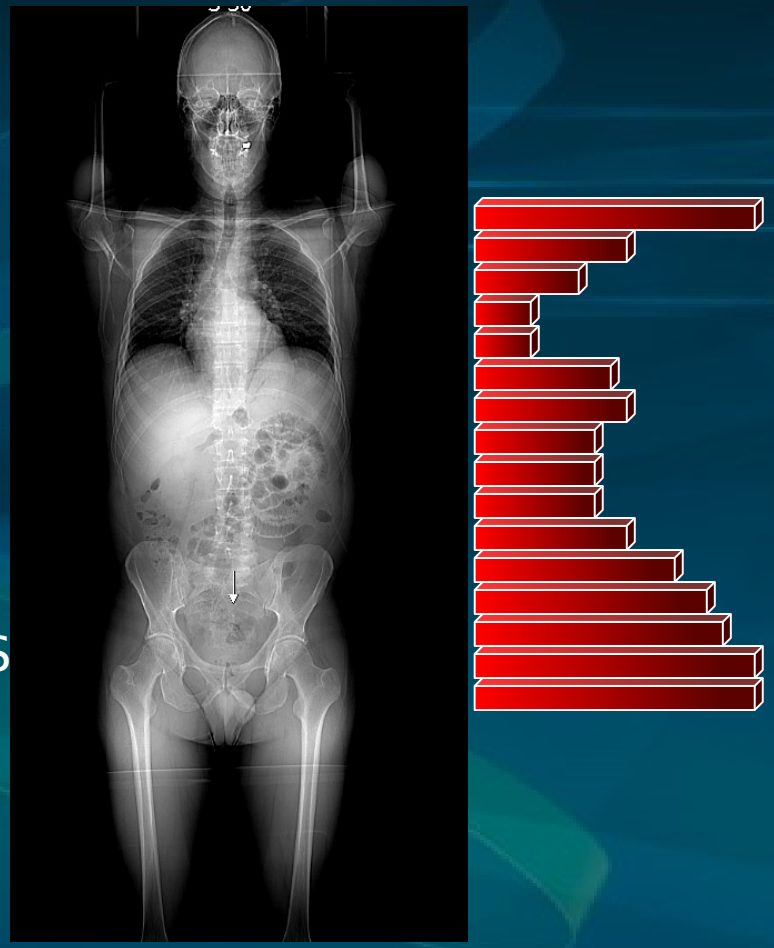


Image distributed under a CC0 1.0 License

Should we use lead shielding for patients?

Should we use lead shielding for patients?

Generally, no.

Patient Shielding

Source optimization techniques are much more effective

Lead can increase the dose via AEC

Most fetal exposure is from internal scatter

ACR, AAPM, NCRP, ADA, ESR

Strategy: Protection for Operators

Strategy: Use Protective Barriers

Lead Apron

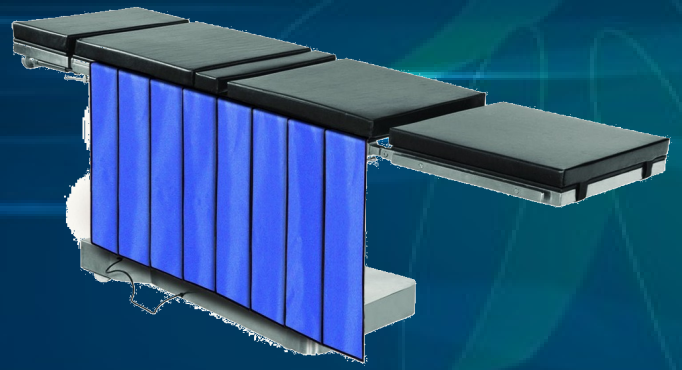
Front Shield 0.35mm lead equivalent for general fluoroscopy

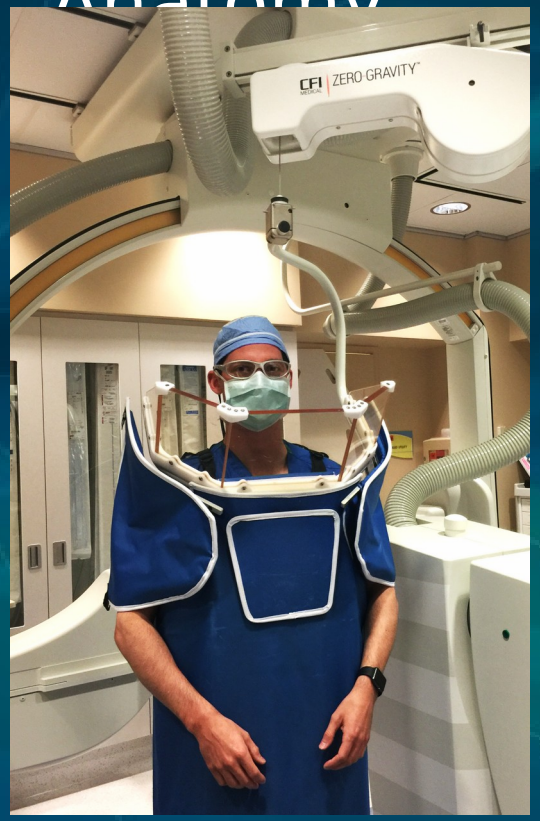
Full Wrap 0.25mm + 0.25mm for higher workload

Effectiveness is energy dependent, but generally 85-95% for the shielded anatomy[14]

Strategy: Use Protective Barriers

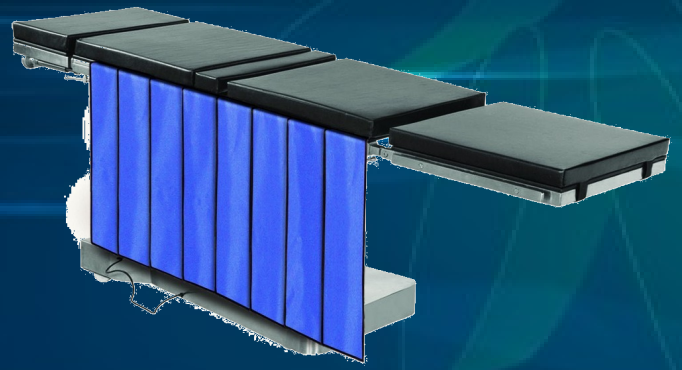
Additional Barriers for Unshielded Anatomy

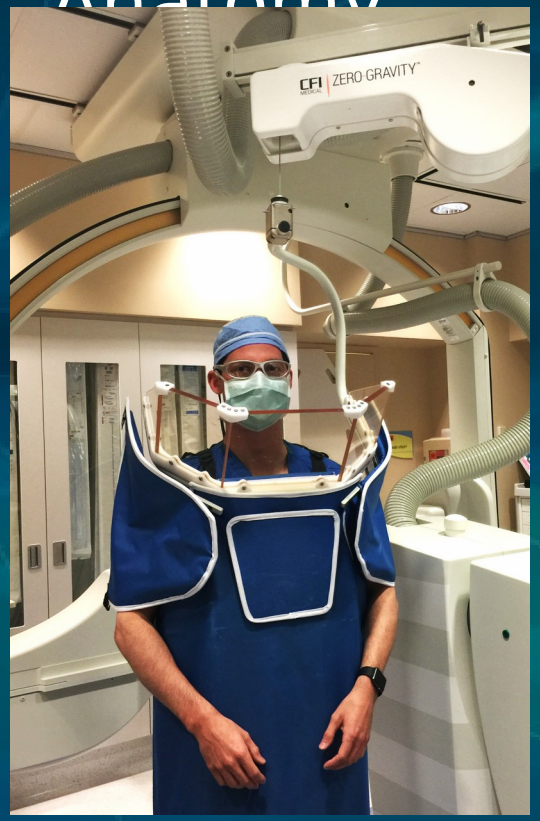




Strategy: Use Protective Barriers

Additional Barriers for Unshielded Anatomy

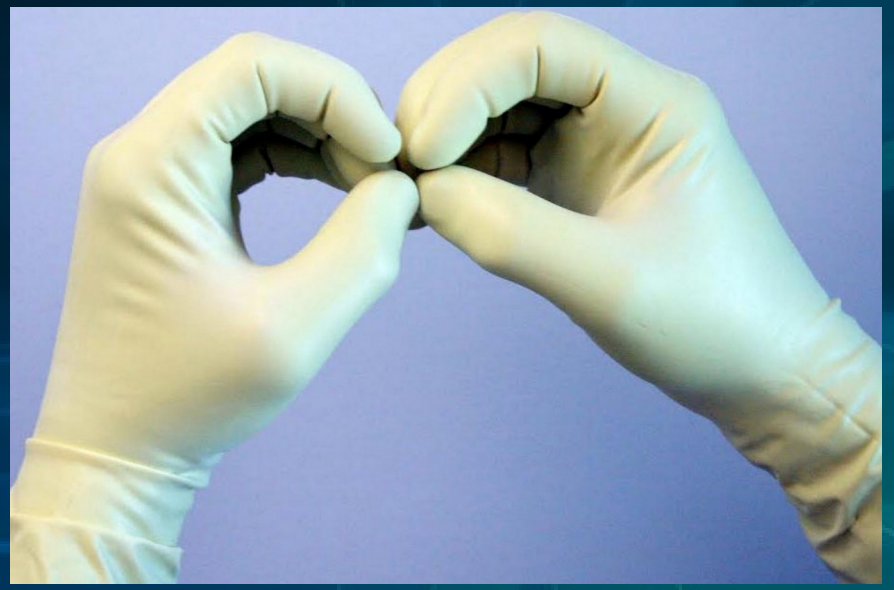




Lens Dose Reduction
Glasses: 3-fold
Drapes: 25-fold
Ceiling Shield: 100-fold

Strategy: Use Protective Barriers

Additional Barriers for Unshielded Anatomy



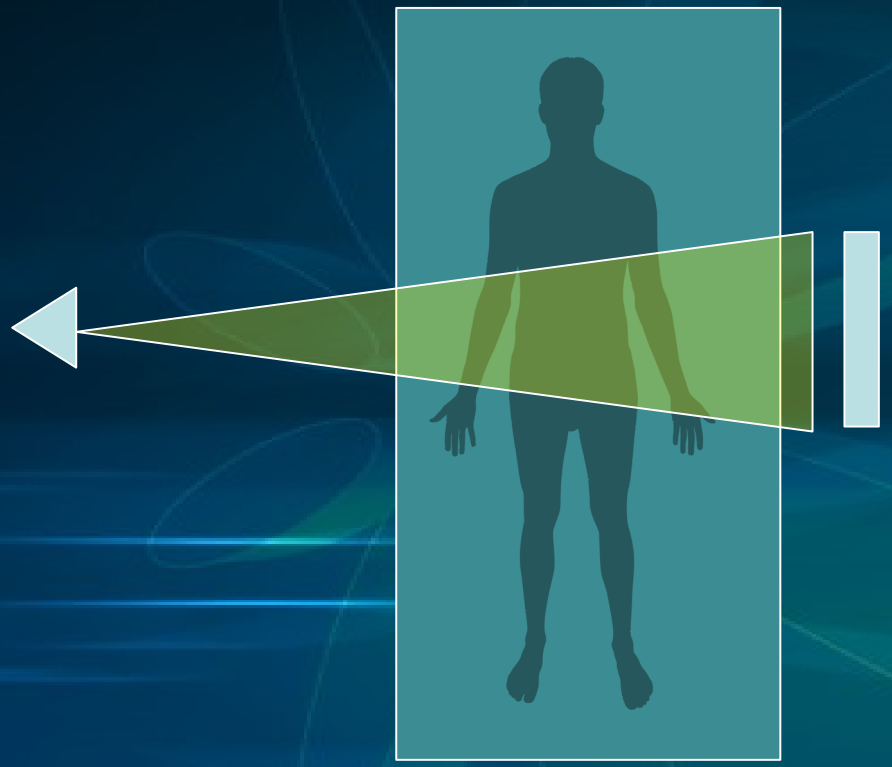
Leaded Gloves

Block scattered radiation

Not intended for direct exposure, and may increase hand dose due to compensatory increase in voltage and less careful technique[14]

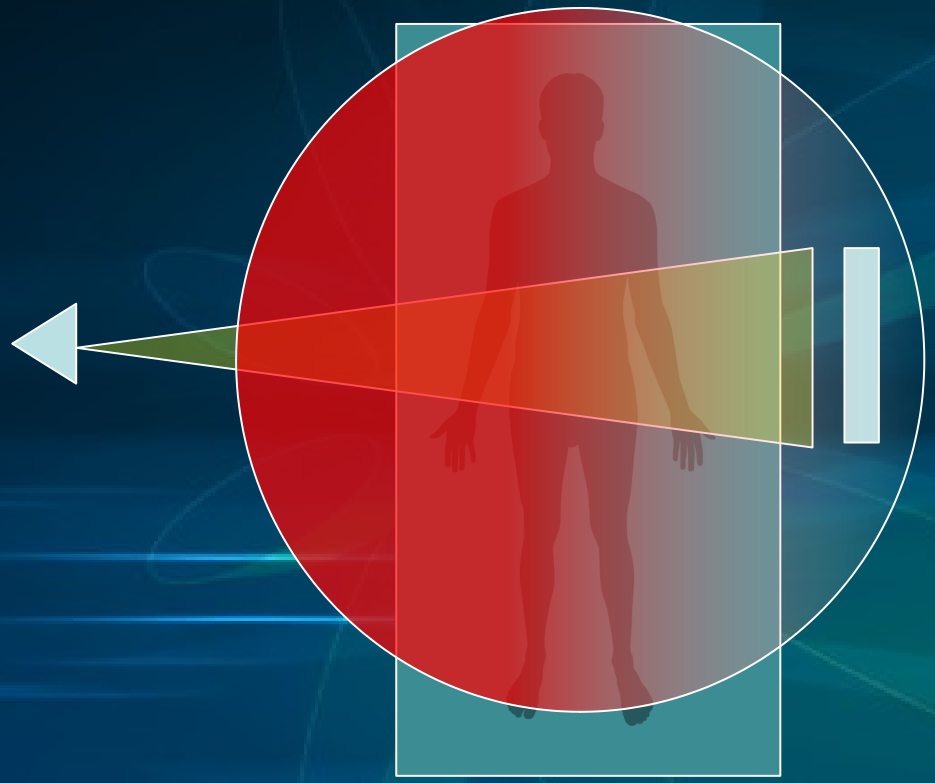
Strategy: Operators should optimize geometric factors by standing in the lowest dose zone possible

Strategy: Optimize Geometric Factors



The operator should stand:

Strategy: Optimize Geometric Factors



The operator should stand:

- ✓ Opposite the x-ray source
- ✓ As far as possible from the field

Scattered radiation is higher on the side of the source, and decreases with the square of distance[27]

Strategy: Measure and Monitor Radiation Exposure

Strategy: Measure and Monitor Radiation Exposure

For Physicians

Appropriate use of radiation dosimeter badges

Badge worn at collar level over protective lead apron

Additional badge worn under the lead if 2-badge dosimetry is used

Ring dosimeter if high extremity exposure is likely

Strategy: Measure and Monitor Radiation Exposure

For Physicians

Appropriate use of radiation dosimeter badges

Badge worn at collar level over protective lead apron

Additional badge worn under the lead if 2-badge dosimetry is used

Ring dosimeter if high extremity exposure is likely

For Patients

Reporting and Reviewing Dose History

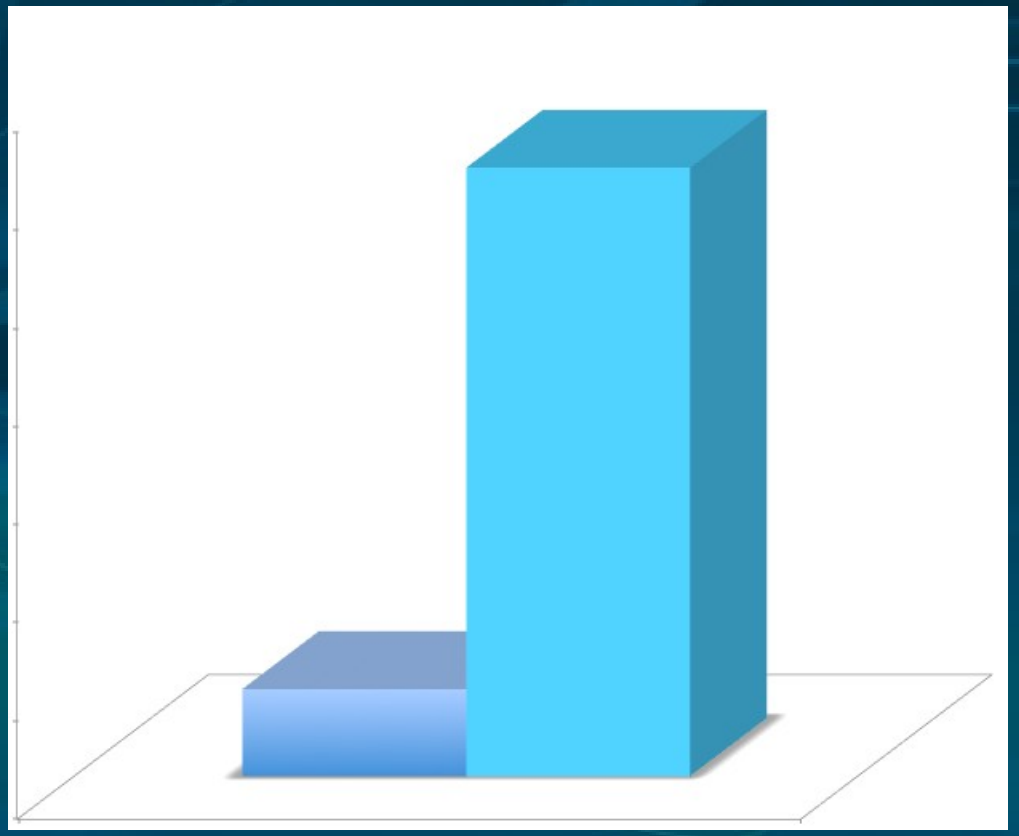
Record exposure in imaging reports

Track cumulative patient exposure

- Patient-managed exposure record
- Practice-level record keeping
- Third party payors

Medical Radiation is Increasing

7-fold increase in the per-capita exposure to medical radiation from 1980 to 2006[1]



Medical Radiation is Increasing

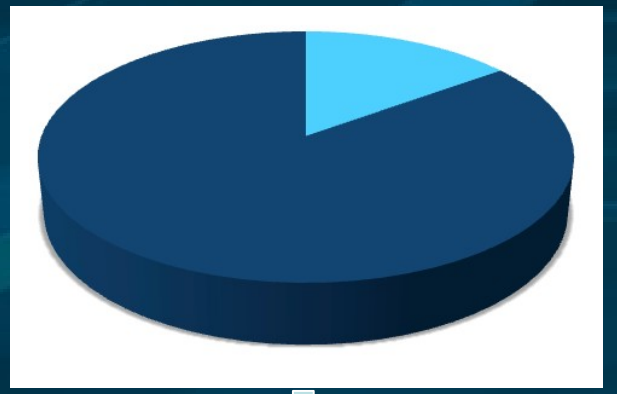
7-fold increase in the per-capita exposure to medical radiation from 1980 to 2006[1]

Annual total medical radiation to the US population is comparable to radiation released from Chernobyl accident[2]

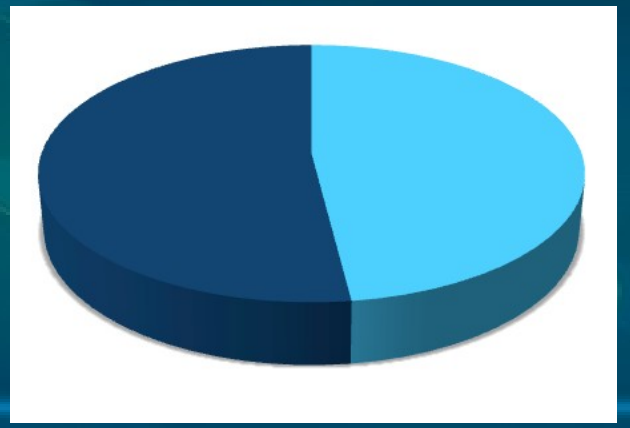
Medical Radiation is Increasing

7-fold increase in the per-capita exposure to medical radiation from 1980 to 2006[1]

Percentage of total annual radiation dose from medical radiation increased from 15% to 48% from 1980 to 2006[1]



15%



48%

Reasons for the Increase

Reasons for the Increase

Advances in Imaging Technology

Reasons for the Increase

Advances in Imaging Technology

Busier settings require faster throughput

Reasons for the Increase

- Advances in Imaging Technology
- Busier settings require faster throughput
- Increased Patient Demand

Reasons for the Increase

- Advances in Imaging Technology
- Busier settings require faster throughput
- Increased Patient Demand
- Fear of litigation

Reasons for the Increase

- Advances in Imaging Technology
- Busier settings require faster throughput
- Increased Patient Demand
- Fear of litigation
- Lack of radiation safety training

Media Attention

The New York Times

We Are Giving Ourselves Cancer

By RITA F. REDBERG and REBECCA SMITH-BINDMAN JAN. 30, 2014

Ben Jones

DESPITE great s
treatment, cance
stubbornly high a
heart disease as t
death in the Unit
we and many oth
an important cul
medical practices
irradiating ourse

The use of medic
dose radiation —
has soared in the
resulting exposu
has increased mo
the 1980s and 20
National Council
& Measurements
CT scans (a serie

The Washington Post

Health & Science

Should you worry about the radiation from CT scans?

By Sandra G. Boodman January 4

Jean Hanvik decided that enough was enough. When a painful intestinal inflammation flared in 2014, the 55-year-old benefits communications consultant balked at her doctor's recommendation that she undergo another abdominal CT scan — her fourth in eight years.

Tampa Bay Times

WINNER OF 10 PULITZER PRIZES

Average child may get 7 radiation scans by age 18

Associated Press

Monday, January 3, 2011 10:19pm

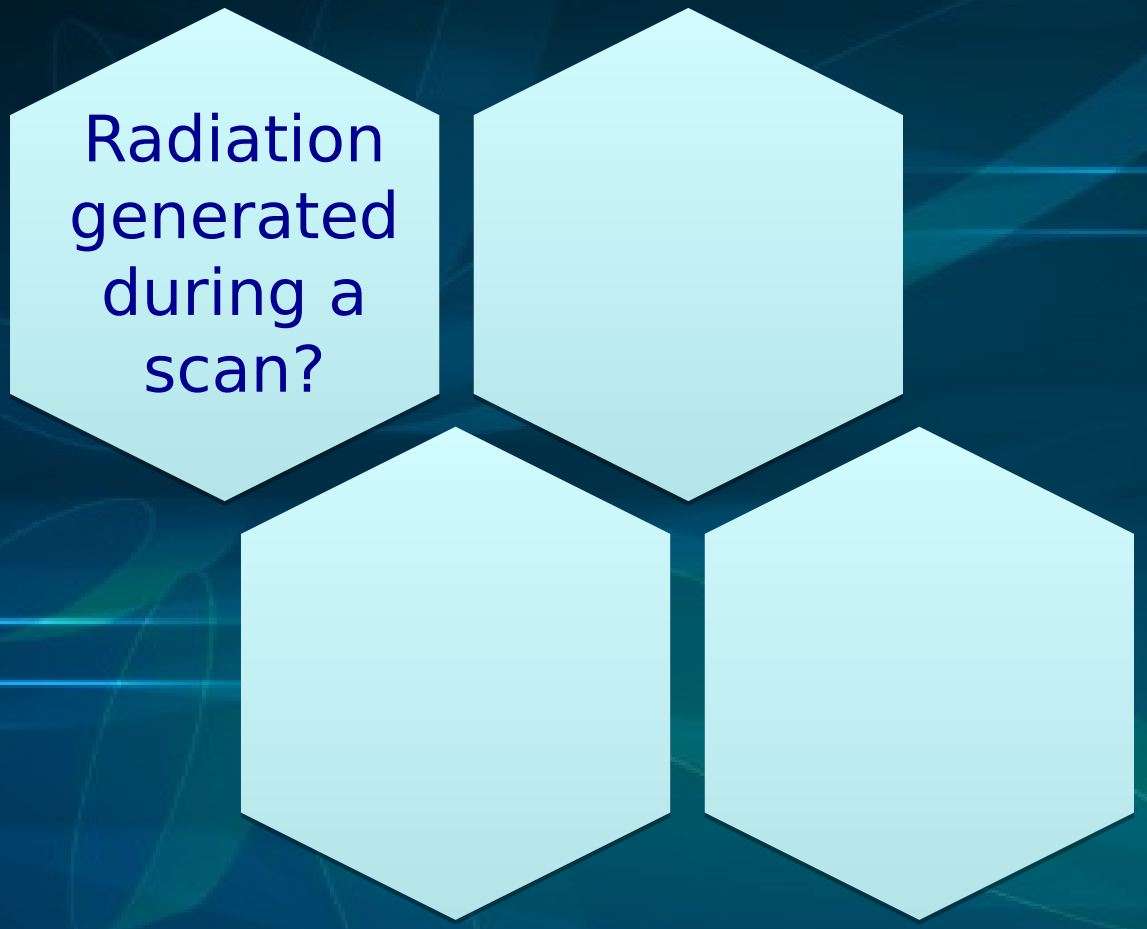
The first large study to examine the use of X-rays, CT scans and other medical radiation in chi
average child will get more than seven radiation scans by age 18, a potentially worrisome trend

Most of the scans involve X-rays, which use relatively little radiation. But there is growing con
which entail far more radiation and can raise the risk for cancer, particularly in children.

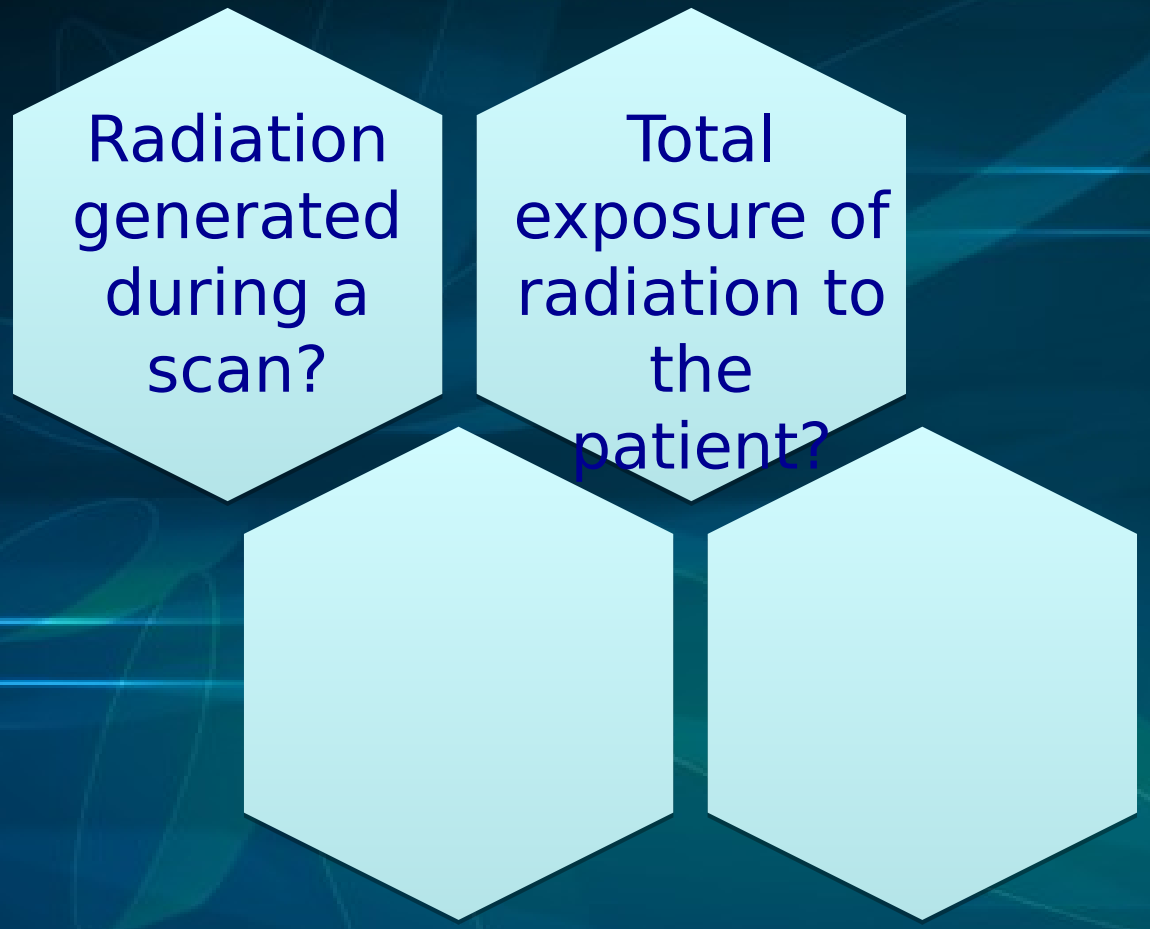
Understanding Radiation Dose

How Do We Talk About Dose?

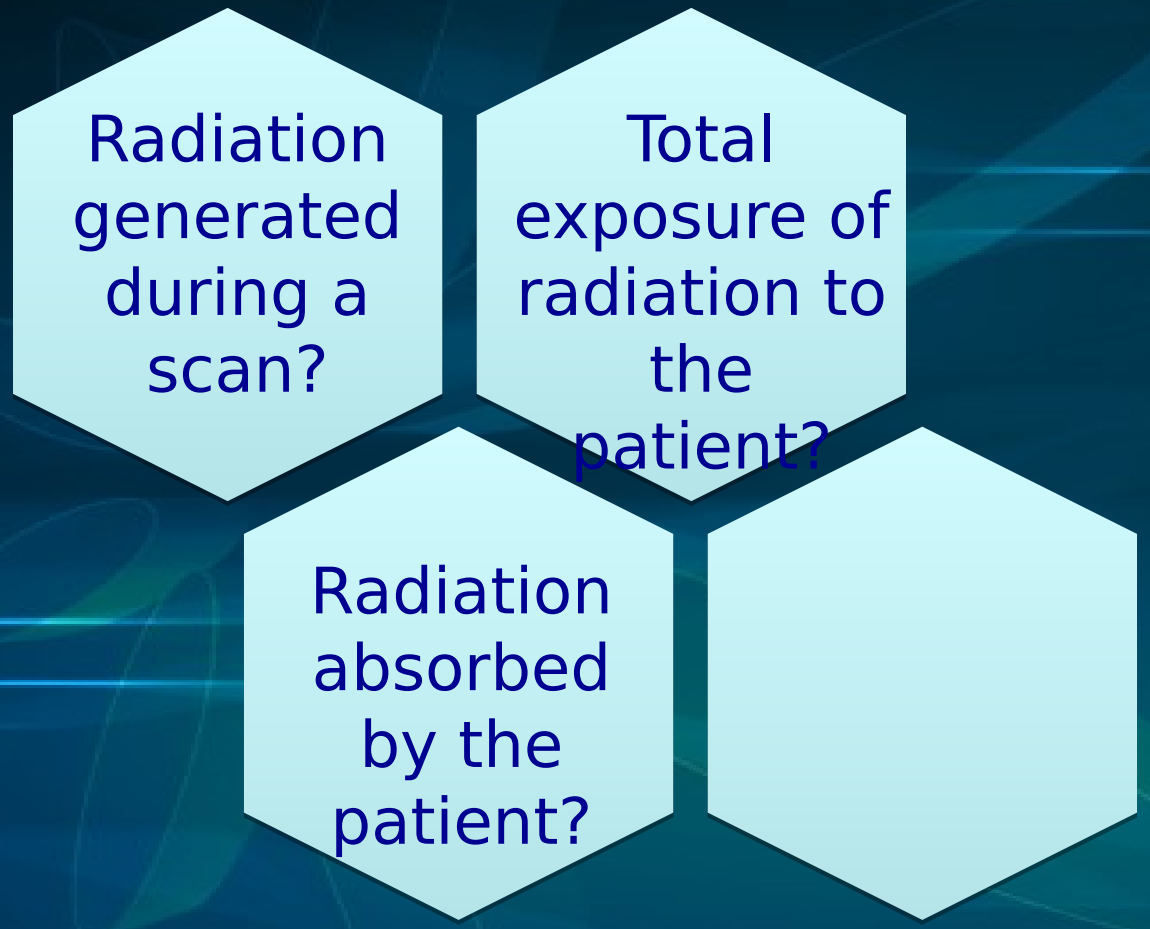
How Do We Talk About Dose?



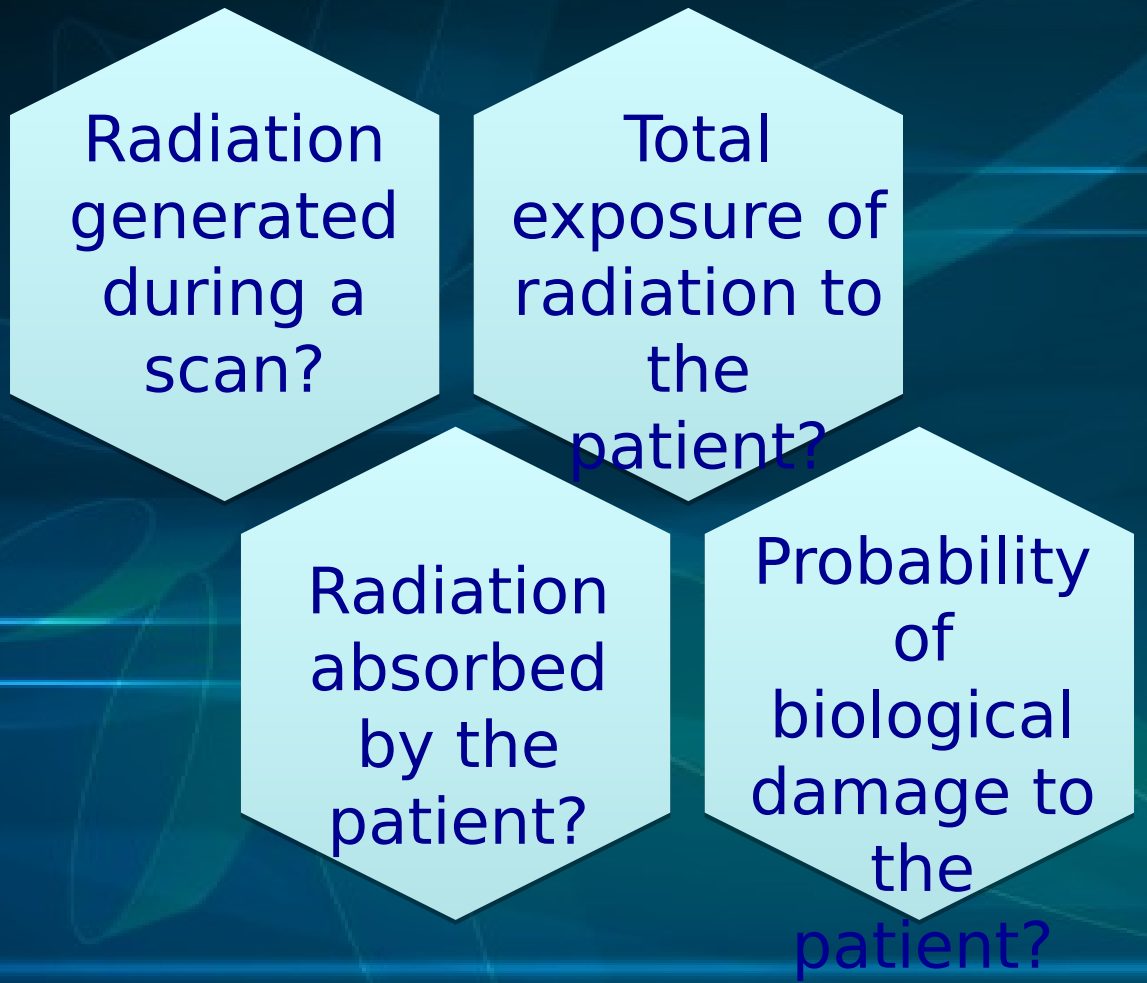
How Do We Talk About Dose?



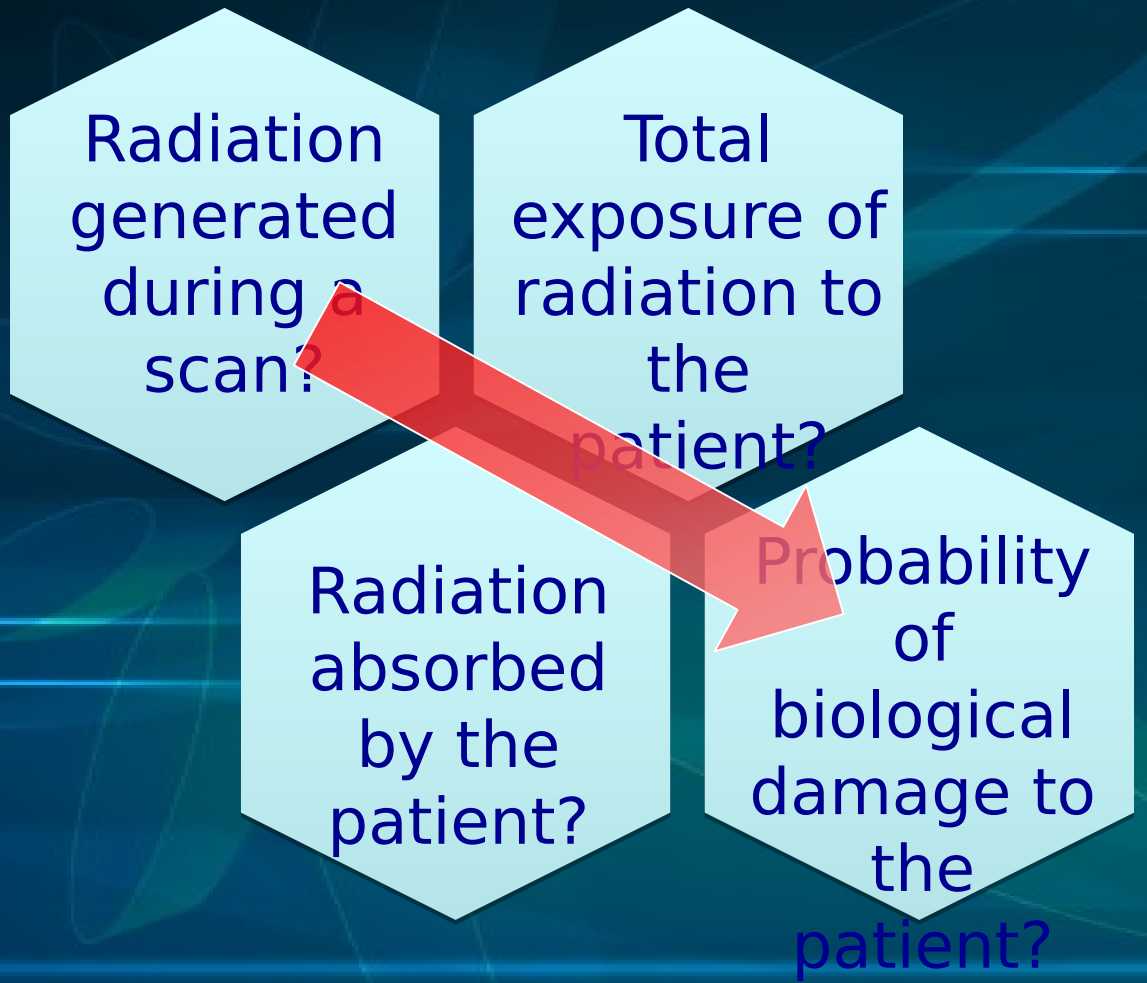
How Do We Talk About Dose?



How Do We Talk About Dose?

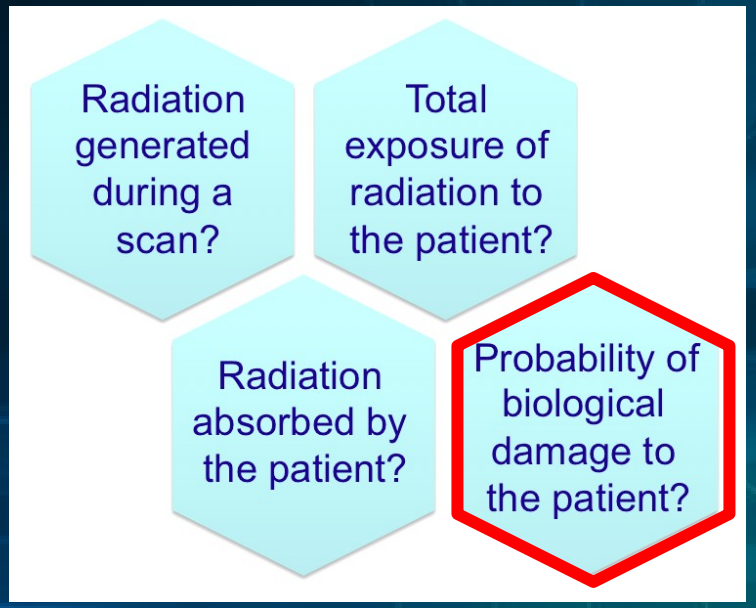

Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

How Do We Talk About Dose?

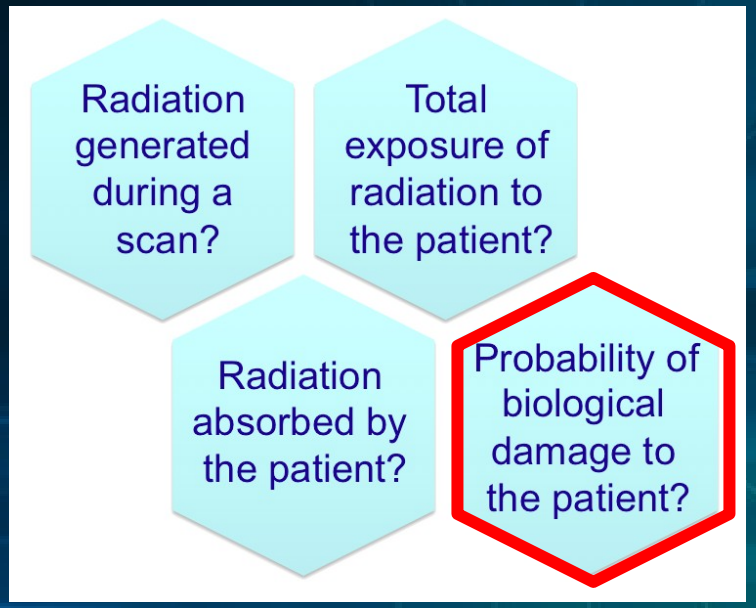

Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

How Do We Talk About Dose?

Exposure (Roentgen, R)


Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

How Do We Talk About Dose?

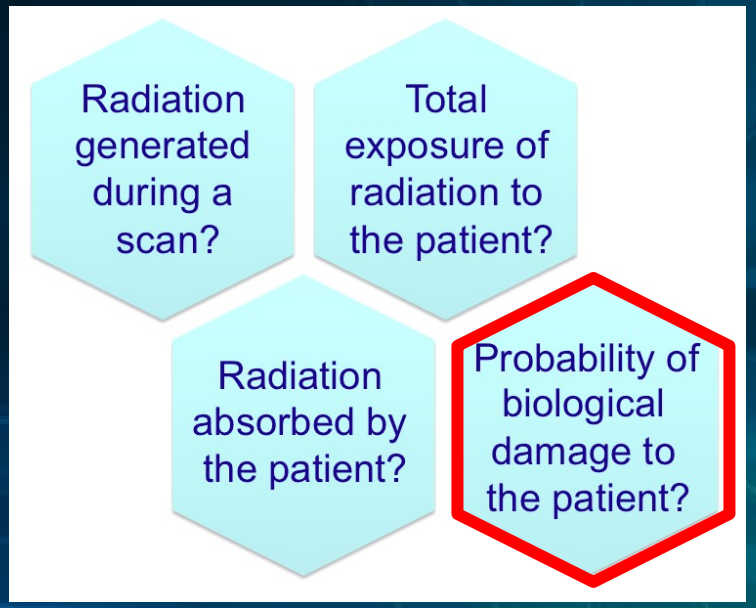

Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

Exposure (Roentgen, R)

X conversion factor

Absorbed Dose (Gray, Gy)

How Do We Talk About Dose?


Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

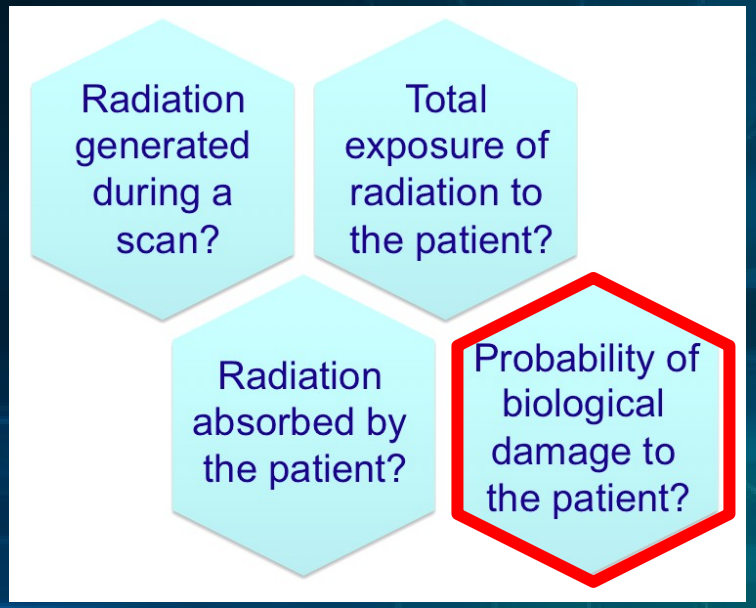
Exposure (Roentgen, R)

X conversion factor

Absorbed Dose (Gray, Gy)

X Σ (*tissue factor,...)*

How Do We Talk About Dose?


Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

Exposure (Roentgen, R)

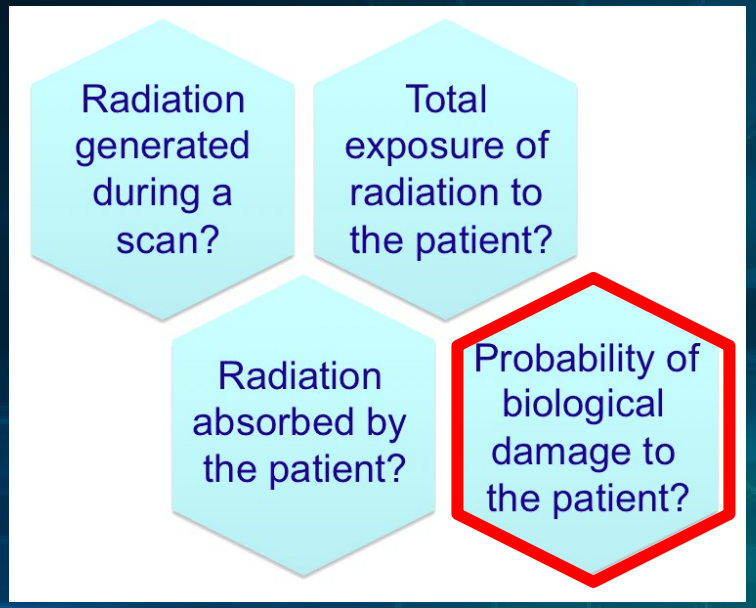
X conversion factor

Absorbed Dose (Gray, Gy)

X Σ (*tissue factor,...)*

Effective Dose (Sievert, mSV)

How Do We Talk About Dose?


Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

1 mSv

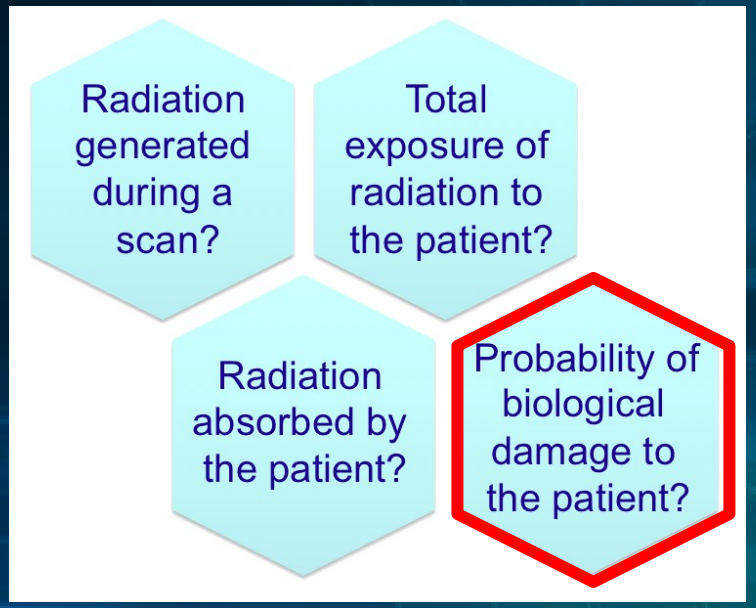
≈

1 / 10,000 risk of cancer diagnosis

1 / 20,000 risk of cancer mortality

Effective Dose (Sievert, mSV)

How Do We Talk About Dose?


Radiation generated during a scan?
Total exposure of radiation to the patient?
Radiation absorbed by the patient?
Probability of biological damage to the patient?

1 mSv

≈

1 / 10,000 risk of cancer diagnosis

1 / 20,000 risk of cancer mortality

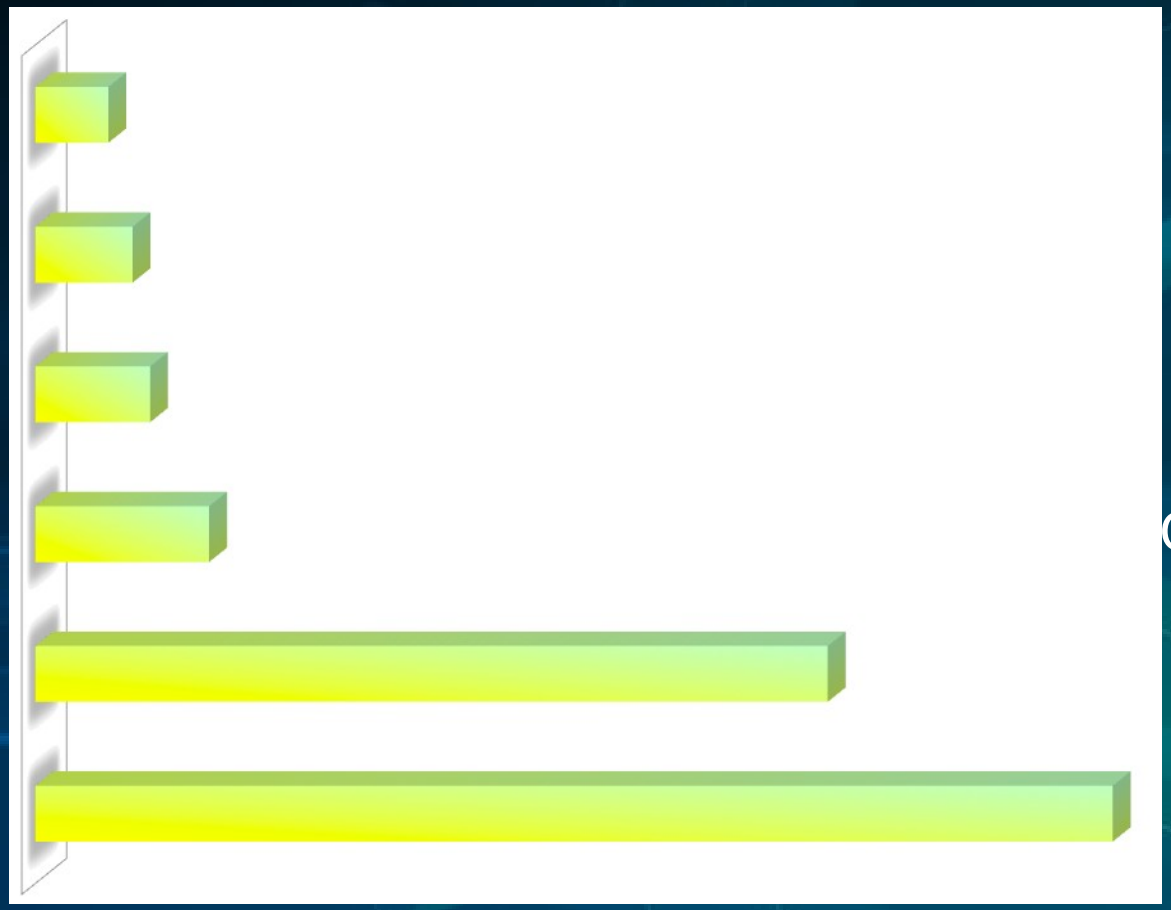
(Lifetime cancer incidence: 40%)

Effective Dose (Sievert, mSV)

ICRP Tissue Weighting Factors

Organ / Tissue	w_t
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Breast	0.12
Remainder tissues (combined)	0.12
Gonads	0.08
Bladder	0.04
Esophagus	0.04
Liver	0.04
Thyroid	0.04
Bone surface	0.01
Brain	0.01
Salivary glands	0.01
Skin	0.01

Everyday Dose Estimates



CO)

Inhaled (Radon)

3.1 mSv Total Annual Background[1]

Everyday Dose Estimates

3.1 mSv Total
Annual Background

Everyday Dose Estimates

Transcontinental Flight[3]
0.03 mSv (3 days BRE*)

*BRE =
Background
Radiation
Equivalent

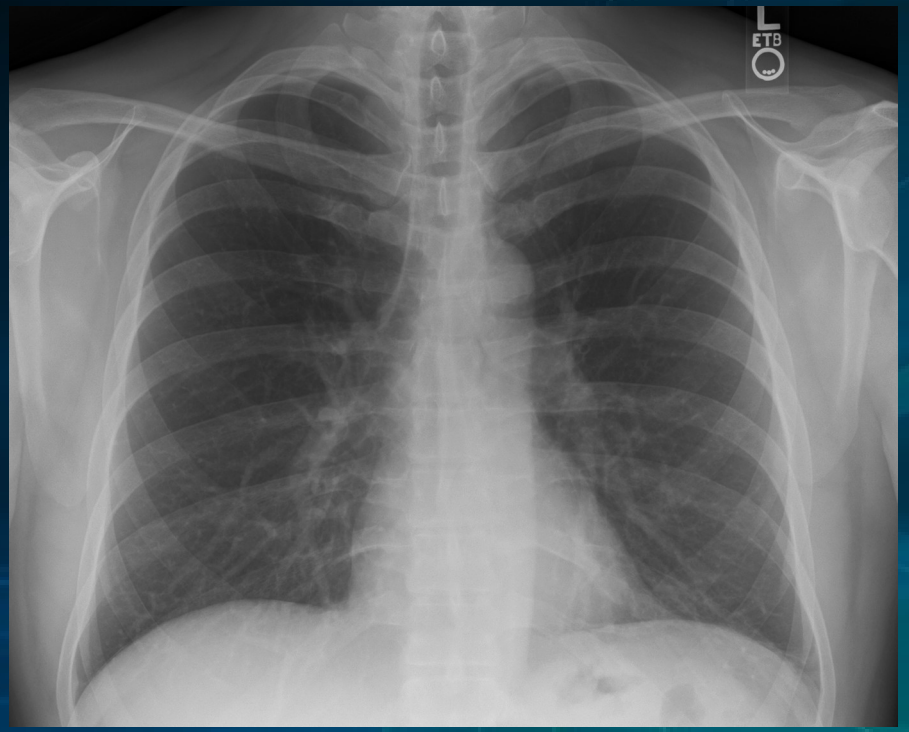
3.1 mSv Total
Annual Background

Everyday Dose Estimates

1 pack-year of smoking[4]
0.36 mSv (36 days BRE)

3.1 mSv Total
Annual Background

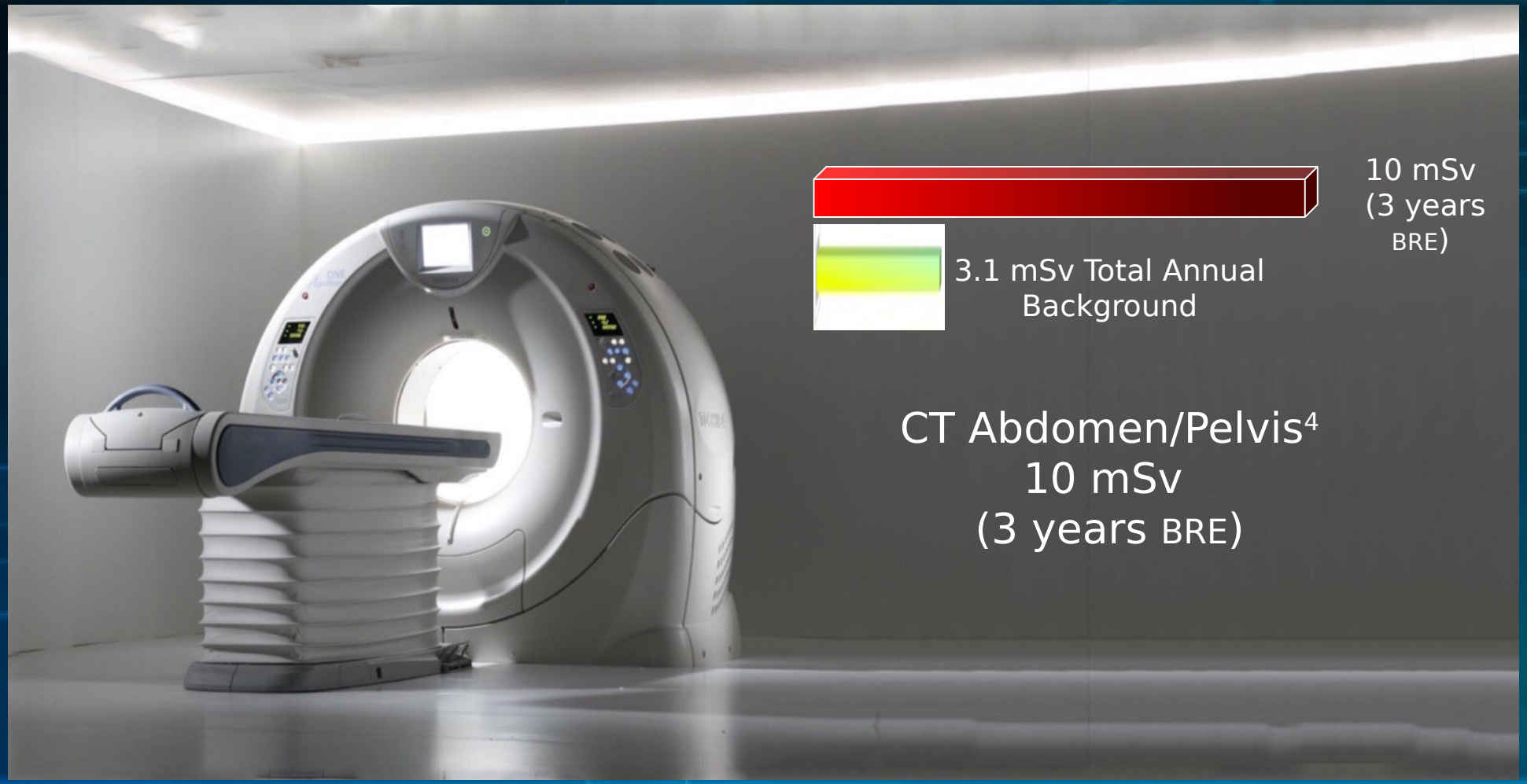
Everyday Dose Estimates



Chest X-ray[4]
0.1 mSv (10 days BRE)

3.1 mSv Total
Annual Background

Everyday Dose Estimates



The Risks of Radiation

The Risks of Radiation

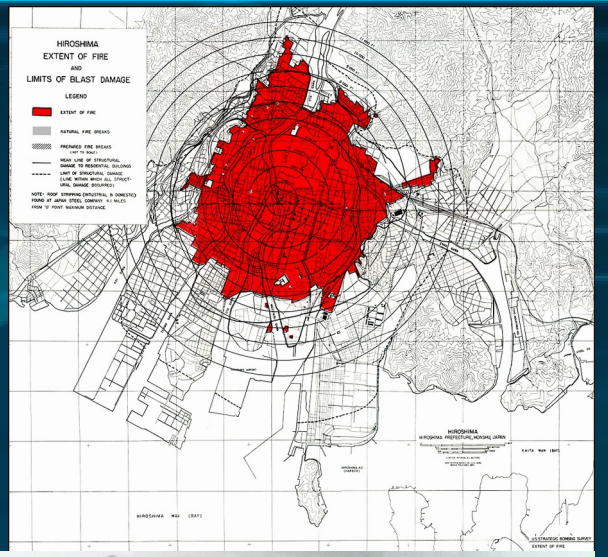
Epidemiology: Observing radiation exposed populations

Nuclear industry workers
Chernobyl cleanup workers
Medical occupational exposure
Radiotherapy patients
Airline pilots

The Risks of Radiation

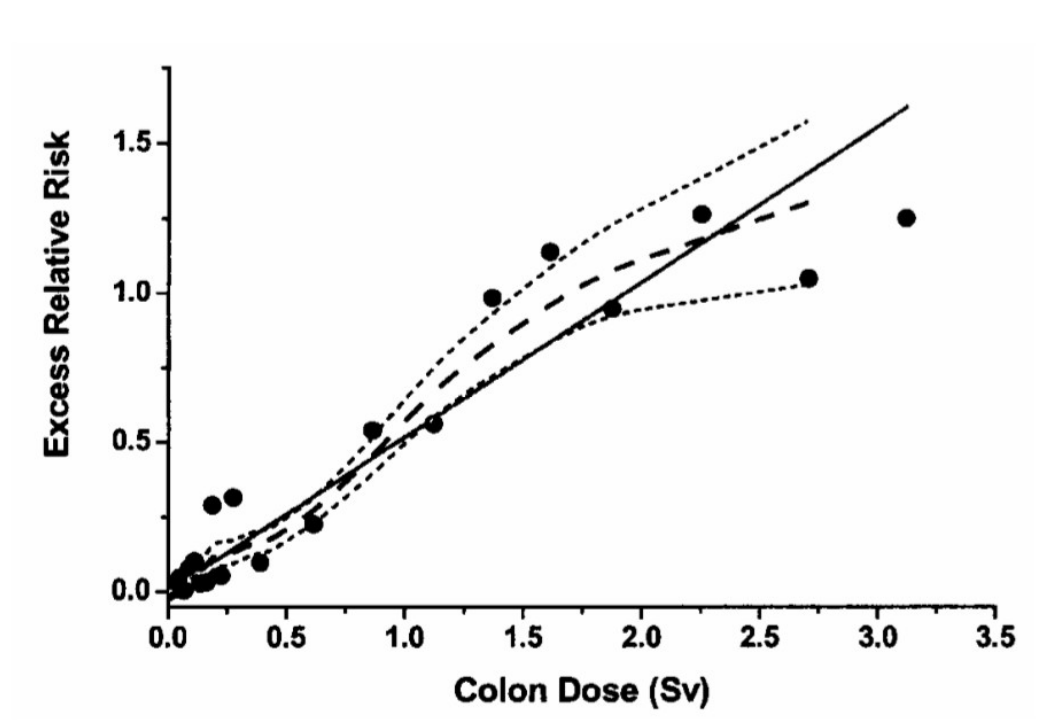
Atomic Bomb Survivors

Large dispersion of whole-body doses
Robust longitudinal follow-up
Allows estimation of dose-response curve
Allows estimation of age-sensitivity



The Risks of Radiation

Solid tumor cancer mortality risk in atomic bomb survivors[5]



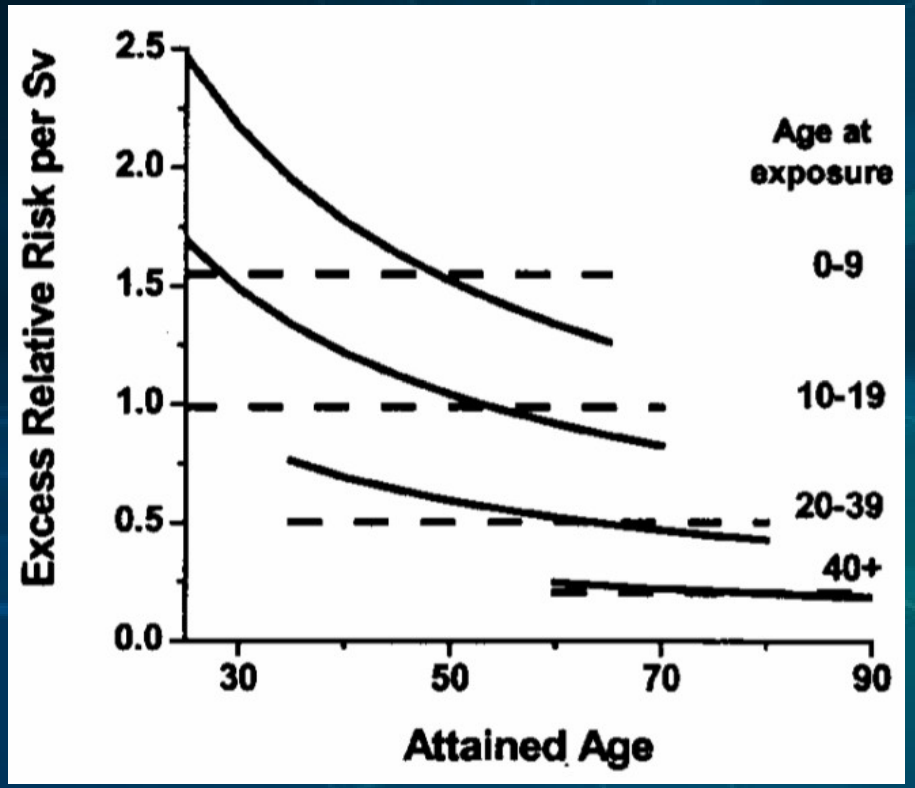
Linear Dose Response

No Lower Radiation Dose Threshold for Cancer Risk

Preston, D.L., Y. Shimizu, D.A. Pierce, A. Suyama, and K. Mabuchi. 2003. Studies of mortality of atomic bomb survivors. Report 13: Solid cancer and noncancer disease mortality: 1950-1997. Radiat Res 160:381-407.

The Risks of Radiation

Solid tumor cancer mortality risk in atomic bomb survivors[5]

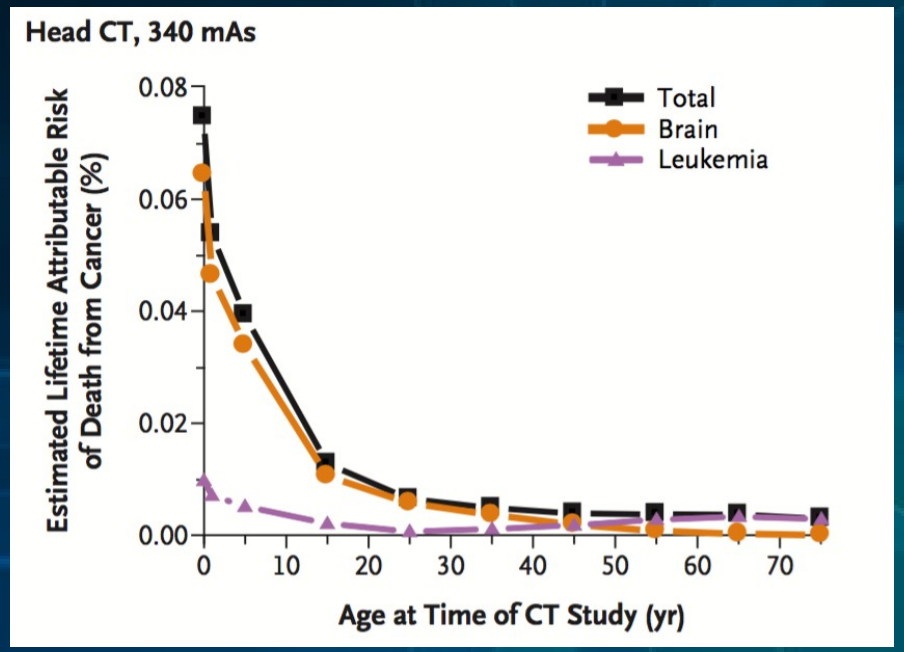


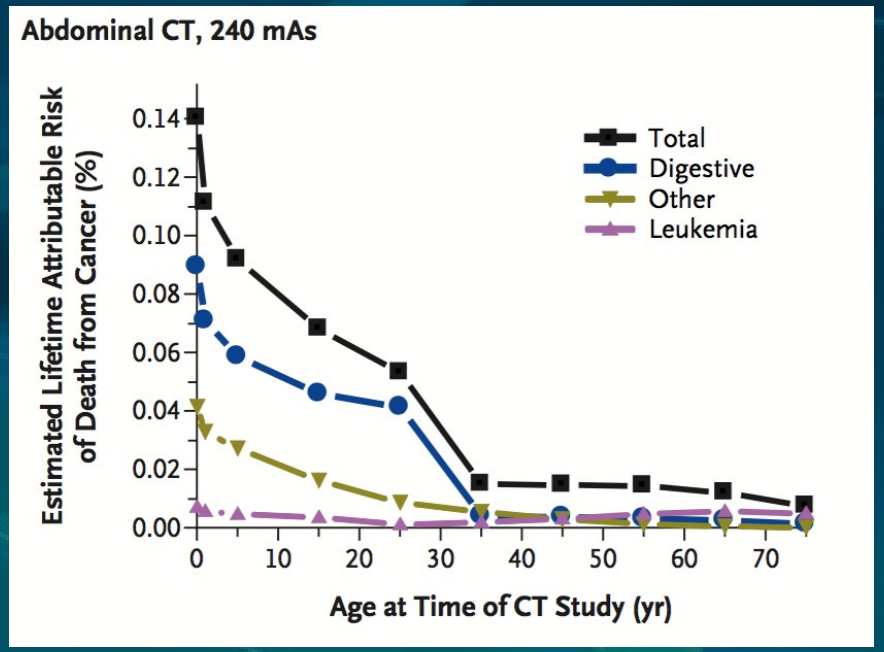
Younger patients at higher risk

Preston, D.L., Y. Shimizu, D.A. Pierce, A. Suyama, and K. Mabuchi. 2003. Studies of mortality of atomic bomb survivors. Report 13: Solid cancer and noncancer disease mortality: 1950-1997. Radiat Res 160:381-407.

The Risks of Radiation

Applying the data to medical imaging patients[6]

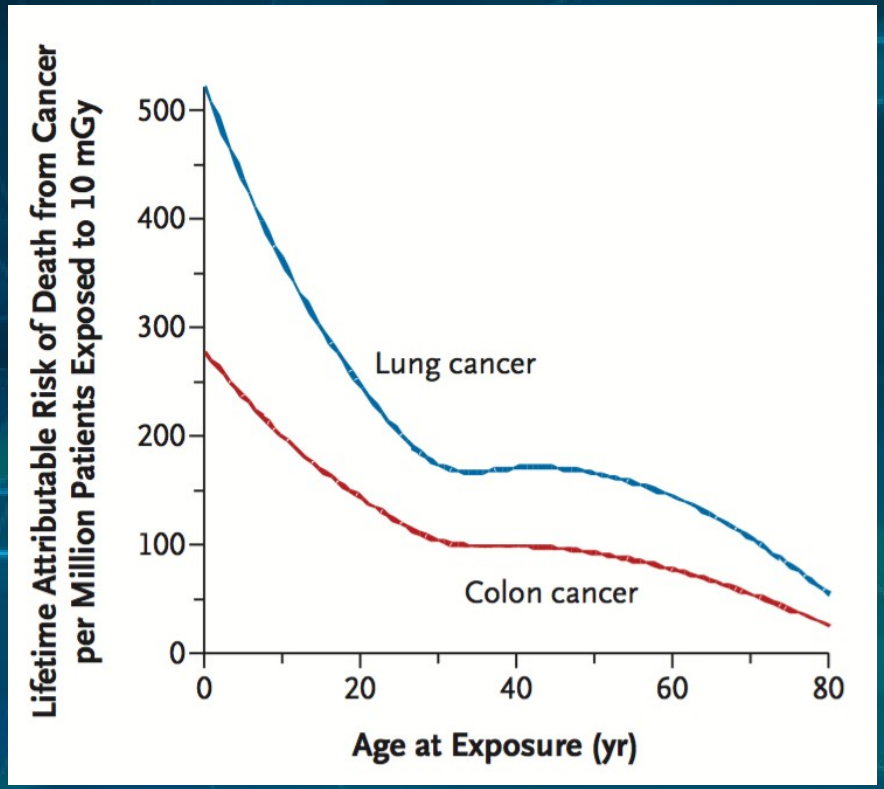




Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med* 2007; **357**: 2277–2284. Reproduced with permission

The Risks of Radiation

Applying the data to medical imaging patients[6]



Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med* 2007; **357**: 2277–2284.

The Risks of Radiation

Applying the data to medical imaging patients[6,28]

2007 NEJM: Brenner *et al* estimate that up to **2% of all cancers** in the US may be attributable to CT use

2025 JAMA: Smith-Bindman *et al* attribute **103,000 cancers to CTs performed in 2023, and potentially 5% of all new cancer** diagnoses annually

The Risks of Radiation

Cancer risk at low doses is controversial[8,9]

Siegel JA, Pennington CW, Sacks B, Welsh JW. 2015. *Am J Clin Oncol*, accepted for publication.

The Birth of the Illegitimate Linear No-Threshold Model

An Invalid Paradigm for Estimating Risk Following Low-dose Radiation Exposure

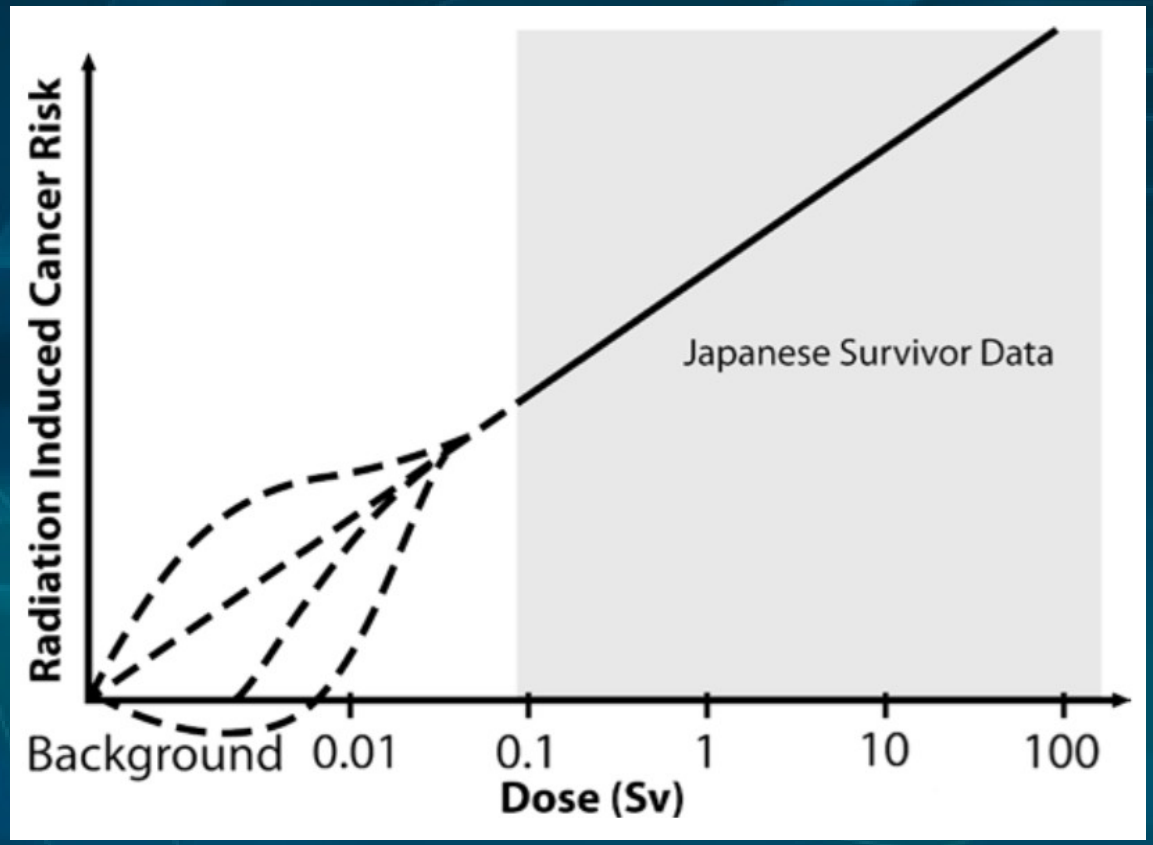
Jeffry A. Siegel, PhD, Charles W. Pennington, MS, MBA,† Bill Sacks, PhD, MD,‡ and James S. Welsh, MS, MD, FACRO§*

Hendee WR, O'Connor MK. *Radiology* 2012;264(2):312–321.

Radiation Risks of Medical Imaging: Separating Fact from Fantasy[1]

The Risks of Radiation

Cancer risk at low doses is controversial[8,9]



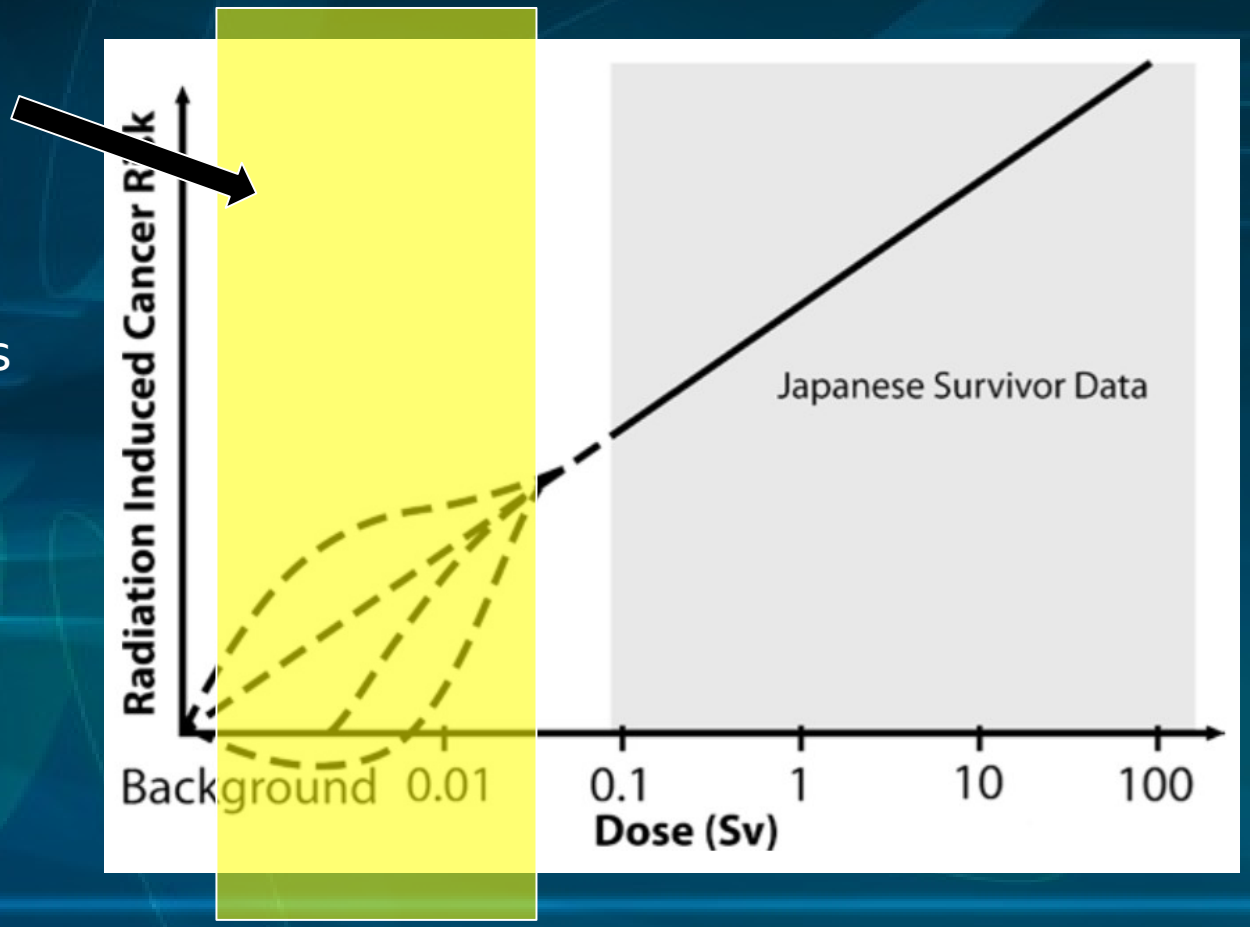
Hendee WR, O'Connor MK. Radiation Risks from Medical Imaging: Separating Facts from Fatnasy. *Radiology* 2012;264(2):312–321. Reproduced with permission.

The Risks of Radiation

Cancer risk at low doses is controversial[7,8]

Dose range for medical imaging

Bomb survivors
- Higher dose ranges
- Instantaneous exposure
- Neutron and other higher energy radiation



The Risks of Radiation

American Association of Physicists in Medicine

“Risks of medical imaging at patient

doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent.”

(12/13/2011)

The Risks of Radiation

Epidemiological studies of medical imaging

Pearce et al find a small but statistically significant risk of leukemia and brain cancer in pediatric patients who underwent CT scans of the head[7]

In 10 years, 1 excess case of leukemia and 1 excess case of brain cancer per 10,000 CT scans

The Risks of Radiation

Cancer (a stochastic risk) is the main risk of concern in medical imaging

The Risks of Radiation

Cancer (a stochastic risk) is the main risk of concern in medical imaging

There are deterministic (threshold) risks due to cell death from radiation exposure[10]:

The Risks of Radiation

Cancer (a stochastic risk) is the main risk of concern in medical imaging

There are deterministic (threshold) risks due to cell death from radiation exposure[10]:

Cataracts	> 500 mSv
Erythema	2,000 mSv
Sterility	2,500-3,500 mSv
Radiation Sickness	2,000 mSv
LD_{50}	4,000-5,000 mSv
Fetal loss, IUGR, MR	…

The Risks of Radiation

Cancer (a stochastic risk) is the main risk of concern in medical imaging

There are deterministic (threshold) risks due to cell death from radiation exposure[10]:

The New York Times

After Stroke Scans, Patients Face Serious Health Risks

By **WALT BOGDANICH** JULY 31, 2010

When Alain Reyes's hair suddenly fell out in a freakish band circling his head, he was not the only one worried about his health. His co-workers at a shipping company avoided him, and his boss sent him home, fearing he had a contagious disease.

Radiation in Pregnancy

“An abdominal radiograph performed to determine fetal head position”

Radiograph distributed under a CC 3.0 License[11]

Radiation in Pregnancy

< 50 mSv

50 - 500 mSv

Time Post Conception				
Blastogenesis (up to 2 wks)	Organogenesis (2 –7 wks)	Fetogenesis		
		(8–15 wks)	(16 –25 wks)	(26 –38 wks)
Noncancer health effects NOT detectable				
Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (noncancer) health effects	• Incidence of major malformations may increase slightly • Growth retardation possible	• Growth retardation possible • Reduction in IQ possible (up to 15 points, depending on dose) • Incidence of severe mental retardation up to 20%, depending on dose	**Noncancer health effects unlikely**	

Radiation in Pregnancy

Below 50 mSv fetal dose, no teratogenic effect

Time Post Conception				
Blastogenesis (up to 2 wks)	Organogenesis (2 –7 wks)	Fetogenesis (8–15 wks)	(16 –25 wks)	(26 –38 wks)
Noncancer health effects NOT detectable				
Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (noncancer) health effects	• Incidence of major malformations may increase slightly • Growth retardation possible	• Growth retardation possible • Reduction in IQ possible (up to 15 points, depending on dose) • Incidence of severe mental retardation up to 20%, depending on dose	**Noncancer health effects unlikely**	

Radiation in Pregnancy

Below 50 mSv fetal dose, no teratogenic effect

Time Post Conception				
Blastogenesis (up to 2 wks)	Organogenesis (2 –7 wks)	Fetogenesis (8–15 wks)	(16 –25 wks)	(26 –38 wks)
Noncancer health effects NOT detectable				
Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (noncancer) health effects	• Incidence of major malformations may increase slightly • Growth retardation possible	• Growth retardation possible • Reduction in IQ possible (up to 15 points, depending on dose) • Incidence of severe mental retardation up to 20%, depending on dose	**Noncancer health effects unlikely**	

Above 50 mSv fetal dose, the vulnerable period is 0-15 weeks

Radiation in Pregnancy

Below 50 mSv fetal dose, no teratogenic effect

Time Post Conception				
Blastogenesis (up to 2 wks)	Organogenesis (2 –7 wks)	Fetogenesis (8–15 wks)	(16 –25 wks)	(26 –38 wks)
Noncancer health effects NOT detectable				
Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (noncancer) health effects	• Incidence of major malformations may increase slightly • Growth retardation possible	• Growth retardation possible • Reduction in IQ possible (up to 15 points, depending on dose) • Incidence of severe mental retardation up to 20%, depending on dose	Noncancer health effects unlikely	

Above 50 mSv fetal dose, the vulnerable period is 0-15 weeks

After 16 weeks gestational age, no detectable teratogenic effect from dose up to 500 mSv[12]

Radiation in Pregnancy

Risk of cancer from fetal exposure

Fetal Dose	**Childhood Cancer Risk[12]**
Background	0.3%
< 50 mSv	0.3% - 1%
50-500 mSv	1% - 6%

Radiation in Pregnancy

Estimated Fetal Radiation Dose

Examination	**Fetal Dose[13]**
Chest x-ray	
Abdominal x-ray	
CT head	
CTA chest (PE)	
CT abdomen/pelvis	

Radiation in Pregnancy

Estimated Fetal Radiation Dose

Examination	**Fetal Dose[13]**
Chest x-ray	**0.002 mSv**
Abdominal x-ray	
CT head	
CTA chest (PE)	
CT abdomen/pelvis	

Radiation in Pregnancy

Estimated Fetal Radiation Dose

Examination	**Fetal Dose[13]**
Chest x-ray	**0.002 mSv**
Abdominal x-ray	**1-3 mSv**
CT head	
CTA chest (PE)	
CT abdomen/pelvis	

Radiation in Pregnancy

Estimated Fetal Radiation Dose

Examination	**Fetal Dose[13]**
Chest x-ray	**0.002 mSv**
Abdominal x-ray	**1-3 mSv**
CT head	**0 mSv**
CTA chest (PE)	
CT abdomen/pelvis	

Radiation in Pregnancy

Estimated Fetal Radiation Dose

Examination	**Fetal Dose[13]**
Chest x-ray	**0.002 mSv**
Abdominal x-ray	**1-3 mSv**
CT head	**0 mSv**
CTA chest (PE)	**0.2 mSv**
CT abdomen/pelvis	

Radiation in Pregnancy

Estimated Fetal Radiation Dose

Examination	**Fetal Dose[13]**
Chest x-ray	**0.002 mSv**
Abdominal x-ray	**1-3 mSv**
CT head	**0 mSv**
CTA chest (PE)	**0.2 mSv**
CT abdomen/pelvis	**25 mSv**

Radiation Doses in Medicine

Data published by the ACR
RadiologyInfo.org
ImageWisely.org

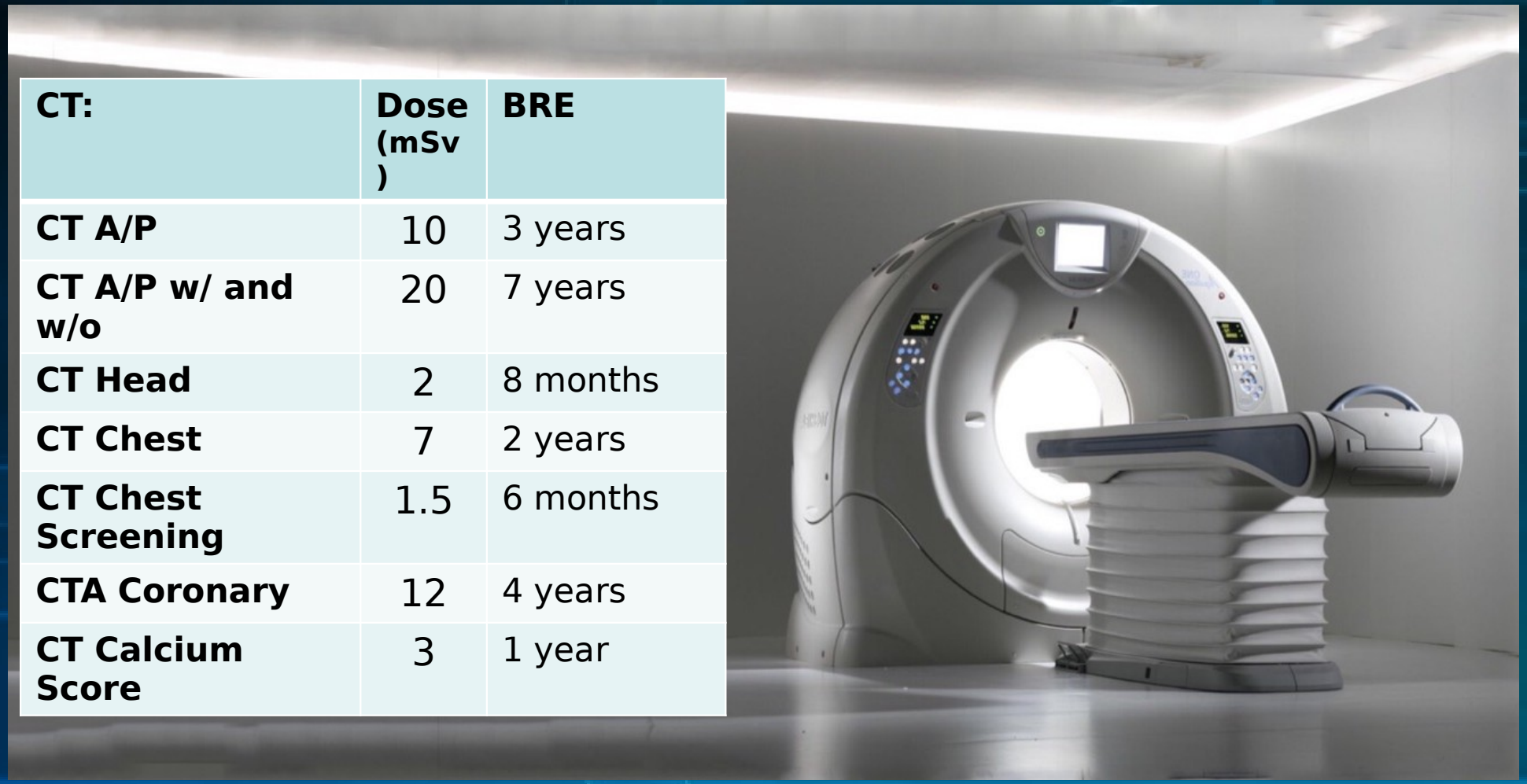
Radiography

Radiograph:	Dose (mSv)	BRE*
Extremity	0.001	3 hours
CXR	0.1	10 days
Mammography	0.4	7 weeks
DEXA	< 0.001	Negligible
Spine	1.5	6 months
UGI Fluoroscopy	6	2 years
Barium Enema Fluoroscopy	8	3 years

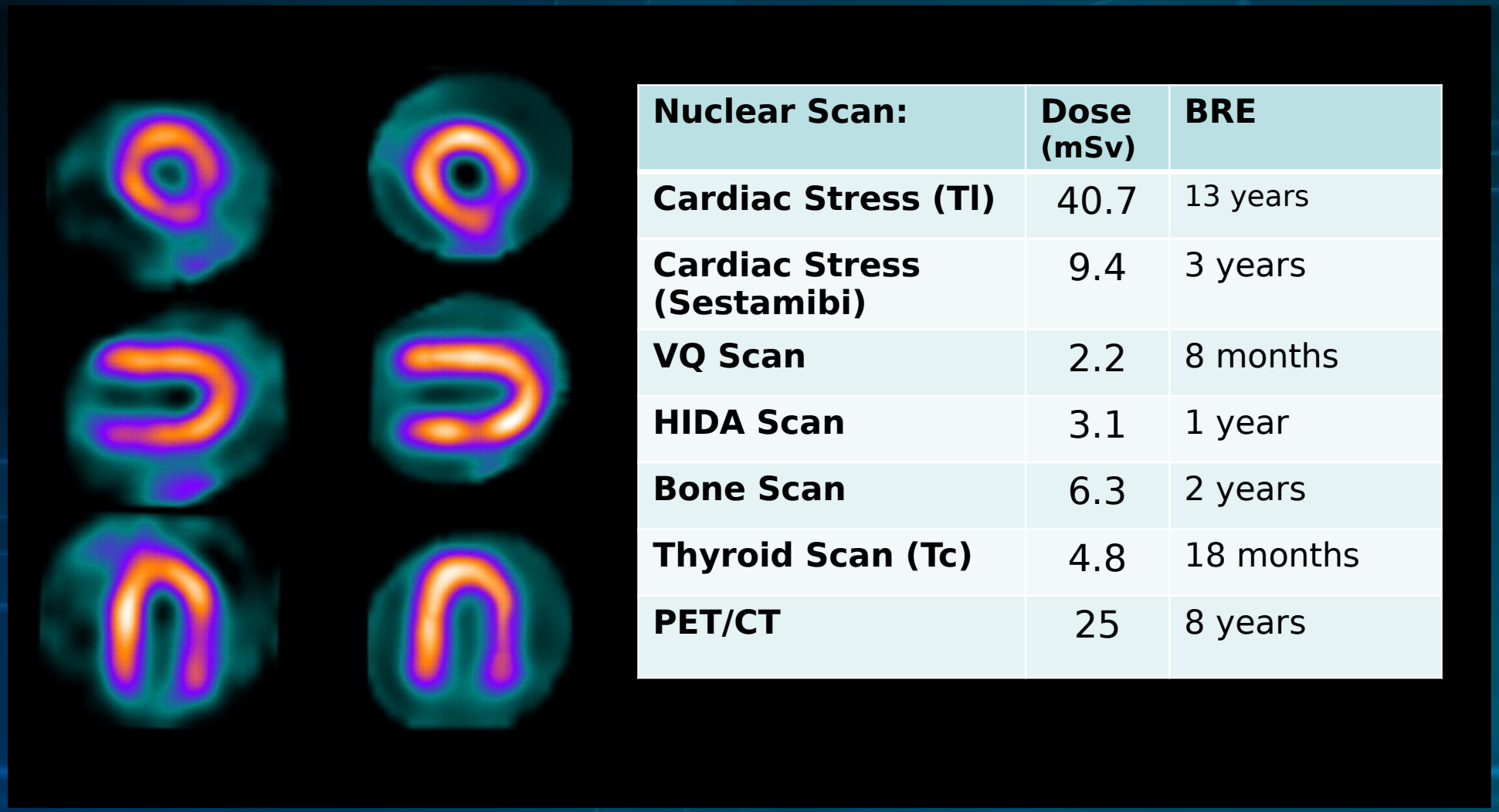
BRE = Background Radiation Equivalent

CT

CT:	Dose (mSv)	BRE
CT A/P	10	3 years
CT A/P w/ and w/o	20	7 years
CT Head	2	8 months
CT Chest	7	2 years
CT Chest Screening	1.5	6 months
CTA Coronary	12	4 years
CT Calcium Score	3	1 year



Nuclear Medicine



Nuclear Scan:	Dose (mSv)	BRE
Cardiac Stress (Tl)	40.7	13 years
Cardiac Stress (Sestamibi)	9.4	3 years
VQ Scan	2.2	8 months
HIDA Scan	3.1	1 year
Bone Scan	6.3	2 years
Thyroid Scan (Tc)	4.8	18 months
PET/CT	25	8 years

Interventional Radiology & Cardiology

Procedure:	Dose (mSv)	BRE
Cerebral Angiography	0.8 - 19.6	Variable
Coronary Angiography	2 - 15.8	Variable
Coronary PCI	6.9 - 57	Variable
TIPS	20 - 180	Variable
Pelvic Vein Embolization	60	Variable

Radiation Doses to Physicians

Occupational Radiation Doses

Mixed general IR	2-15 mSv	per 1000 cases[14]
Coronary PCI	0.2-9 mSv	per 1000 cases[24]
Endovascular surgery	23 mSv	per 1000 cases[14]
ERCP	21 mSv	per 1000 cases[14]
Hip arthroplasty	3.1 mSv	per 1000 cases[25]

Occupational Radiation Doses

Mixed general IR	2-15 mSv	per 1000 cases[14]
Coronary PCI	0.2-9 mSv	per 1000 cases[24]
Endovascular surgery	23 mSv	per 1000 cases[14]
ERCP	21 mSv	per 1000 cases[14]
Hip arthroplasty	3.1 mSv	per 1000 cases[25]

Relative Annual Staff Doses[15]

Physicians	3.00 mSv/y
Nurses	1.34 mSv/y
Technologists	0.60 mSv/y

Occupational Radiation Doses

Mixed general IR	2-15 mSv	per 1000 cases[14]
Coronary PCI	0.2-9 mSv	per 1000 cases[24]
Endovascular surgery	23 mSv	per 1000 cases[14]
ERCP	21 mSv	per 1000 cases[14]
Hip arthroplasty	3.1 mSv	per 1000 cases[25]

Relative Annual Staff Doses[15]

Physicians	3.00 mSv/y
Nurses	1.34 mSv/y
Technologists	0.60 mSv/y

NRC Regulatory Limits

50 mSv/y

Managing Radiation Risks

A study is ordered → A study is performed → Keep dose As Low As Reasonably Achievable (ALARA)

A study is ordered

A study is performed

Keep dose As Low As Reasonably Achievable (ALARA)

Strategy: Appropriate Utilization

Strategy: Appropriate Utilization

Slovis, *et al*:
Up to 30% of CT scans are not justified by medical need[16]

Medicare claims data show overutilization of “double” CT scans w/ and w/o contrast[17]

The use of practice guidelines improves appropriate utilization of imaging[18]

In Summary

Medical radiation is an increasingly important contributor to radiation exposure

At the low radiation doses used for medical imaging, the risk of health effects is small but likely real

There is a duty to minimize unnecessary exposure and keep necessary exposure
ALARA:

Ensure appropriate utilization of imaging
Select the appropriate contrast protocol for CT
Practice informed consent
Optimize imaging hardware
Optimize examination protocol
Use fluoroscopy gently
Use protective barriers
Optimize radiation geometry
Measure and monitor radiation exposure
Educate patients, physicians and students

References

1. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States (report 160). Bethesda, Md: National Council on Radiation Protection and Measurements; 2009.
2. Amis ES Jr Butler PF Applegate KE et al. American College of Radiology, American College of Radiology white paper on radiation dose in medicine. J Am Coll Radiol 2007;4 (5) 272- 284.
3. Bottollier-Depois JF, Chau Q, Bouisset P, Kerlau G, Plawinski L, Lebaron-Jacobs L. Assessing exposure to cosmic radiation during long-haul flights. Radiat Res 153(5 Pt. 1):526–532; 2000.
4. Patient Safety - Radiation Dose in X-Ray and CT Exams. http://www.radiologyinfo.org/en/info.cfm?pg=safety-xray Published by the American College of Radiology.
5. Preston, D.L., Y. Shimizu, D.A. Pierce, A. Suyama, and K. Mabuchi. 2003. Studies of mortality of atomic bomb survivors. Report 13: Solid cancer and noncancerdisease mortality: 1950-1997. Radiat Res 160:381-407.
6. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. NEnglJ Med2007; 357: 2277–2284.
7. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *Lancet*2012;380:499-505.
8. Siegel JA, Pennington CW, Sacks B, Welsh JW. The Birth of the illegitimate linear no-threshold model. An invalid paradigm for estimating risk following low-dose radiation exposure. 2015. *Am J Clin Oncol*, accepted for publication.
9. Hendee WR, O'Connor MK. Radiation risks of medical imaging: Separating fact from fantasy. Radiology 2012;264(2):312-321.
10. Peck, D. J., PhD, & Samei, E., PhD. (n.d.). How to Understand and Communicate Radiation Risk. http://www.imagewisely.org/imaging-modalities/computed-tomography/medical-physicists/articles/how-to-understand-and-communicate-radiation-risk Published by the American College of Radiology.
11. James Hellman, MD, CC 3.0 License.
12. Radiation and Pregnancy: A Fact Sheet for Clinicians. (n.d.). Retrieved April 10, 2016, from http://emergency.cdc.gov/radiation/prenatalphysician.asp Published by the Centers for Disease Control.
13. McColloughCH, Schueler BA, Atwell TD, et al. Radiation exposure and pregnancy: when should we be concerned? *RadioGraphics*2007; 27: 909–918.
14. Staff Radiation Protection. https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/4_InterventionalRadiology/fluoroscopy-operating-theatres/fluoroscopy-staff-protection.htm#FULS-FAQ0 Published by the International Atomic Energy Agency.

References

15. K. Chida, Y. Kaga, Y. Haga, N. Kataoka, E. Kumasaka, T. Meguro, and M. Zuguchi, “Occupational dose in interventional radiology procedures,” Am. J. Roentgenol. 200, 138–141 (2013).
16. Slovis TL, Berdon WE. Panel discussion. Pediatr Radiol 2002;32:242-4.
17. Bogdanich, W., & McGinty, J. (2011, June 17). Medicare Claims Show Overuse for CT Scanning. The New York Times.
18. Guite KM, Hinshaw JL, Ranallo FN, Lindstrom MJ, Lee FT Jr. Ionizing radia- tion in abdominal CT: Unindicated multiphase scans are an important source of medically unnecessary exposure. J Am Coll Radiol 2011;8:756-61.
19. Mettler FA, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and nuclear medicine: a catalog. Radiology 2008;248:254-63.
20. Johnson, P. T., Mahesh, M., & Fishman, E. K. (2015). Image Wisely and Choosing Wisely: Importance of Adult Body CT Protocol Design for Patient Safety, Exam Quality, and Diagnostic Efficacy. Journal of the American College of Radiology, 12(11), 1185-1190.
21. Parry RA, Glaze SA, Archer BR, The AAPM/RSNA physics tutorial for residents — fluoroscopy: patient radiation exposure index. Radiographics 2001; 21:1033-1045 p. 1040.
22. Bolch, W., et al., *A video analysis technique for organ dose assessment in pediatric fluoroscopy: applications to voiding cystourethrograms (VCUG).* Medical Physicis, 2003. 30(4): p. 667-680.
23. Mahesh, M. (2001). Fluoroscopy: Patient Radiation Exposure Issues. RadioGraphics, 21(4), 1033-1045.
24. Kim, K. P., Miller, D. L., Balter, S., Kleinerman, R. A., Linet, M. S., Kwon, D., & Simon, S. L. (2008). Occupational Radiation Doses To Operators Performing Cardiac Catheterization Procedures. Health Physics, 94(3), 211-227.
25. Theocharopoulos, N., Perisinakis, K., Damilakis, J., et al., Occupational exposure from common fluoroscopic projections used in orthopaedic surgery, JBJS 85 (2003) 1698-1703.
26. Boland, G.W.L., et al.,*Dose Reduction in Gastrointestinal and Genitourinary Fluoroscopy: Use of Grid-Controlled Pulsed Fluoroscopy.*Am. J. Roentgenol., 2000.175(5): p. 1453-1457.
27. Miller DL, Vañó E, Bartal G, Balter S, Dixon R, Padovani R, et al. Cardiovscular and Interventional Radiology Society of Europe; Society of Interventional Radiology. Occupational radiation protection in interventional radiology: a joint guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology. Cardiovasc Intervent Radiol. 2010;33:230–239.
28. **Smith-Bindman R, Chu PW, Azman Firdaus H, et al.** Projected Lifetime Cancer Risks From Current Computed Tomography Imaging. *JAMA Internal Medicine*. 2025;185(6)

Thank You